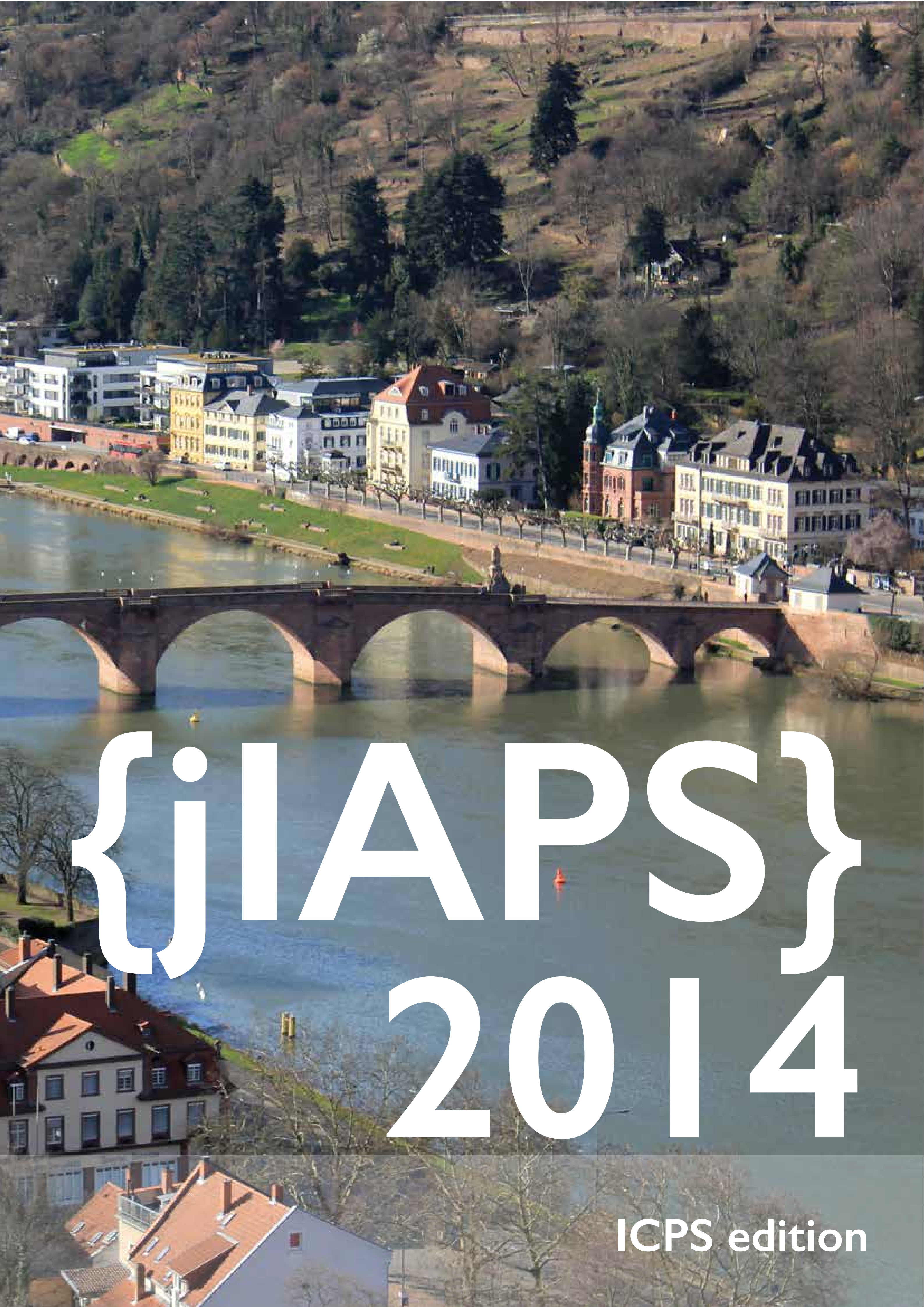

{jIAPS} 2014

ICPS edition

IN THIS ISSUE

{IAPS}
international association of physics students

EDITOR'S NOTE

Welcome to the ICPS 2014 issue of the journal of the International Association of Physics Students. This issue will cover a subset of the submitted articles in the academic year of 2013-2014.

This issue is loaded with seven Physics articles written by students about their research or things which they find interesting. Articles about activities organised by IAPS and our member organisations, the latest news about the next ICPS and the member counties in the association.

The editorial team of jIAPS and the executive committee of IAPS would like to congratulate Anna Fava for winning the jIAPS article contest 2014 with her article "*The quest for a unified theory: Why quantum gravity still proves to be elusive to modern day physicists*" which can be found on page 12.

Hope you have a good time reading the 2014 ICPS edition of jIAPS!

Norbert Bonnici
Editor

PRESIDENT'S LETTER

Dear reader,

IAPS proudly presents selected articles about the activities and events of the association. In addition to a report about the autumn school between the Hungarian physics student association Mafihe and the German physics student association jDPG, you will also find an article about the first edition of PLANCKS, the Physics League Across Numerous Countries for Kick-ass Students. This international competition was organised in Utrecht by A-Eskwadraat for the first time and raised a lot of attention having Stephen Hawking as a guest speaker. Furthermore, an article about a bid for hosting ICPS 2016 in Hungary is provided and the Informal Forum of International Student Organizations (IFISO) is presented, where IAPS is an active partner nowadays. I especially want to emphasize the article about the International Year of Light 2015, which offers an unique opportunity for outreach activities and international collaborations in the forthcoming year.

Enjoy reading through our articles!

Matthias Zimmermann
President of IAPS

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IAPS renews cooperation with IFISO

This year the Executive Committee of the International Association of Physics Students (IAPS) supports the Informal Forum of International Student Organisations (IFISO) with one member in their management team. IAPS has not been a member of IFISO since a couple of years, but this year they became a member once more.

What is IFISO?

The Informal Forum for International Student Organizations is a platform where associations with similar scopes can come together and share experiences on whatever topics they find relevant. IFISO consists of 20 associations, representing more than 2 million students around the world. In spite of working in very different professional areas the IFISO members can to a very high degree learn from each other through best practices and shared events. Thus IFISO is a place for associations to meet, share, discuss and find new inspiration.

While not being a formal entity (no by-laws, no obligations, no fees, no website, no official spokespersons or officers, etc.), IFISO as an informal forum is still quite influential. It creates the necessary environment for international student organisations to collaborate on all possible levels in order to strengthen their capacities through knowledge sharing and identification of synergies.

History

Before the foundation of IFISO it existed as an organisation called IMISO – acronym for Intersectorial Meeting of International Student Organisations. IMISO was established in 1993 for cooperation between the international students organisations based in Europe. It was created in order to improve the chances to receive grants from the European Union. Minutes of IMISO meetings can be found in the ESTIEM archives in Eindhoven.

At the time a multidisciplinary project was needed to get funding from the EU. In 1997 it became registered as an organisation in Belgium and it succeeded in receiving the EU grant for an activity. This project never took place and the money had to be returned and IMISO was dissolved and IFISO was born. In 2008 the first Leadership Summer School was organised for all IFISO members, during this summer school 17 different associations participated, originating from many different countries.

by Peter Van Arkel
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International Year of Light 2015

by Matthias Zimmermann
matthias.zimmermann@iaps.info

A year to highlight the importance of light and light-based technology to the citizens of the world – for this purpose the United Nations proclaimed on 20th December 2013 the year 2015 as the International Year of Light. Optical technologies become more and more important to our daily life. You may for example think of the internet, where data is often transmitted via optical fibers, which allow much higher data rates than wire cables. But there was also a lot of progress done, when it comes to light emitting technologies. LEDs are widely used nowadays due to lower energy consumption and longer lifetimes compared to incandescent light sources. Another very prominent example for a light emitting technology is the laser, which is not only important for DVDs and Blu-ray discs, but also for the manufacturing industry, medicine and for many other branches. Moreover, the interaction between light and matter has been carefully studied and led to a Nobel prize in 2012 for Serge Haroche and David Wineland. It is very likely, that more future technologies will be developed based on their results. But already nowadays it is clear that the problem-solving potential of light is enormous and thus the 21st century is likely to depend as much on light as the 20th century did on electronics.

To promote these technologies and the importance of light, more than 100 partners from more than 85 countries decided to collaborate, among them different scientific unions as the American Physical Society (APS), the American Institute of Physics (AIP), the Deutsche Physikalische Gesellschaft (DPG), the Institute of Physics (IOP), the European Physical Society (EPS) and further societies as The Optical Society (OSA). The International Association of Physics Students (IAPS) is aware of its responsibility and will as well support the International Year of Light as a partner. This year offers an unique possibility to inform the general public about what we – the physicists – are doing and why this is important for the life of everyone and the society as a whole. Furthermore, it is a fascinating international project, in which all member societies of IAPS can get involved and therefore the International Year of Light also offers the possibility for IAPS to strengthen the exchange and the collaboration between physics students from all over the world.

History

It was not by accident, that 2015 has been chosen for the International Year of Light. Besides light-technologies being important nowadays, 2015 also marks the 1000th anniversary since the famous books about optics by the Arabic scientist Ibn al-Haytham appeared. Ibn al-Haytham described in his seven volumes the physiology of the eye, the theory of perception and physical optics such as light travelling at different speeds in different media or atmospheric refraction. Furthermore, he studied natural phenomena as rainbows and eclipses and succeeded in explaining the reflection of light from curved mirrors mathematically.

But also other major scientific contributions related to light celebrate their anniversary in 2015:

1815 – Fresnel described the wave nature of light
1865 – Maxwell studied light as an electromagnetic wave
1915 – Einstein investigated how light behaves in space and time
1965 – the cosmic microwave background was discovered, which is an important evidence for the Big Bang
1965 – Charles Kuen Kao, nobel laureate of 2009, did his fundamental work on optical fibers.

The year 2015 offers us the possibility to celebrate these important milestones related to the study of light and optics.

Events and Activities

To raise the awareness of how optical technologies influence our daily life many different events are planned all around the world in 2015 and this is also the chance for you to get involved in the International Year of Light!

INTERNATIONAL YEAR OF LIGHT 2015

You may think of organising local events related to light and light-based technologies. An example are LightTalks!, which could focus on optical illusions, slow light or other interesting features of light. There are also certain resources available which are aimed at primary and secondary school students as videos by Bill Nye the Science Guy, where different optical phenomena are explained easily understandable. Light and Laser Education Kits exist, with which university students can share their knowledge about this topic with secondary school students. A large number of conferences and other major events about light and optical technologies will take place in 2015. Especially, the Opening Ceremony in Paris on the 19th and 20th January 2015 should be mentioned. Furthermore, a project to bring light to developing and third-world countries without access to electricity will be put into effect. In these countries kerosene lamps are widely used and should now be replaced with healthier bright solar-powered LED lanterns to allow people to work and study after sunset and to light up the world. For all these different kinds of projects, volunteers from all over the world are needed, who support the International Year of Light with their ideas, their motivation and their spirit. And we – as physics students – are certainly one of the groups to be aware of the importance of light and therefore should actively get involved in this outstanding global initiative.

Be prepared for a huge amount of fascinating events and activities in the **International Year of Light 2015**!

More info at: **www.light2015.org**

ICTP ICSU IUPAP IUTAM IUPAB IAU ICO isprs URSI

ICPS 2015 - Zagreb, Croatia

Next year's International Conference of Physics Students (ICPS) will be hosted by the Student section of the Croatian Physical Society, in Zagreb, Croatia. Find out what you can expect at 2015's ICPS in the following article!

The National Committee (NC) Croatia had presented their bid for organising the ICPS 2015 on last year's Annual General Meeting (AGM), and Zagreb was voted as the future host city for the ICPS! Croatian physics students have a long and devoted history at the ICPS – we come in big numbers and high volume, and we definitely like taking charge. We already have two highly successful ICPS organisation projects under our belts – the ICPS in 2000 was held in Zadar, and the one in 2009 in Split – both our gorgeous coastal cities, but something was missing in that equation. The majority of Croatian physics students reside in the Croatian capital, Zagreb, with the headquarters of the NC Croatia located at the Department of Physics at the University of Zagreb.

Zagreb is the largest city in the country, with its metropolitan area population going just slightly over 1 million people, hosting the University of Zagreb, the oldest continuously operating university in Southeastern Europe, as well as the largest university in Croatia, and acting as the cultural, scientific and touristic center of the country. It is a beautiful and old European city, with a highly eventful history, located in the middle of the continental part of Croatia, one of those cities whose streets mostly cover an orthogonal layout – something most tourists very much appreciate. Zagreb is a city that's grown between the Medvednica mountain to the north (hosting one of the FIS World Cup slalom skiing races in the winter, because why not) and the river Sava to the south. There is not much life on the river, unlike in other European cities, so don't bother exploring. The center of the city is located near the main square, where you can find Manduševac, the fountain told to have been the source of the city's name. A passing knight had asked a girl named Manda, to grab him some water (Croatian: zagrabi), giving the fountain the name Manduševac, and the city became known as Zagreb. A good sense of humour seems to come with the territory.

Croatia (Hrvatska) is a relatively small country on the border of Central Europe and the Balkans, it is marked by its wonderfully diverse geography and natural beauties, from the Adriatic sea on the south-west, over the Dinaric Alps, to the plains of Slavonia on the north-east, as well as its nice people. Since a year ago, Croatia has been a member of the European Union, but you can still expect a full measure of the old Yugoslavian friendliness wherever you go. We pride ourselves with remarkable people stemming from our neck of the woods, from Ruđer Bošković, Faust Vrančić (inventor of the parachute), Andrija Mohorovičić, right down to Nikola Tesla. And Croats started the necktie fashion we still have going on in the world. We have had two Nobel prize winners, but none of them in physics – yet. Whether you're interested in idling on the coast, sight-seeing, or absorbing the feel of our young and cozy country, you are bound to find something to your liking.

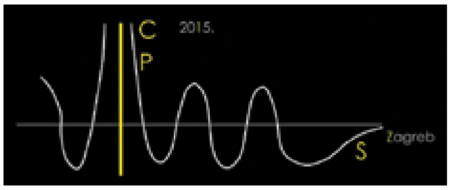
Our equally compact Organising Committee consists of 7 physics students at varying stages of study and with varying experience with the ICPS. We are planning on hosting you at one of our student dorms in the general city center area – everyone in one place, in double rooms. Unfortunately, the Department of Physics is located too far away to make sense to hold the official events there, so we have partnered up with the Faculty of Electrical Engineering and Computing (FER), who have generously provided their facilities for holding lectures and organising other events. FER is one of our most prolific industrial and scientific institutions, and it can be reached in a short 10-minute walk from the dorm. Breakfast, lunch and dinner will all be found in the same building as the lectures, in one of the local student restaurants, and the parties will be held in the electrical engineering students' club (KSET), on the other side of the building, so there will be no walking all over the city on ICPS 2015! The ICPS 2015 is patronised by the University of Zagreb, and the organisation has gained support of various institutions in the city and country.

There are more than 120 planned student lecture slots and 80 poster slots, we are expecting 5 guest lectures from distinguished physicists, sponsor company sessions, visits to the local labs and companies that employ physicists, and we will be organising various activities with the goal of introducing new (and old!) Physics students to fields they have not explored yet. Now that we have the professional aspect of the conference covered, what about everything else? All the classic parties will be held, you can look forward to the obligatory sports, poker tournament, the city tour scavenger hunt, a quiz, and some other events with a bit more of twists and turns. We all love the IPCS and will do whatever is in our power to make everyone feel as comfortable and happy as possible. Our version of the ICPS will stray a little bit from the well-walked line we have been following so far – our goal is to strongly promote communication and popularisation of our favourite field of study. All the lecturers and official representatives are asked to actively participate in the conference, parties included; so if you decide you want to discuss Marxist ideologies with a physicist banker, you will have plenty of opportunity to do so and there will not much that would save them from your charming rhetoric. We are planning on holding a round table on physics popularisation, and depending on shown interest, other discussion events may be organised, as well. There is a reserved slot for the traditional IAPS members' experience exchange, as well as the Annual General Meeting. None of the organisers appreciate driving around in busses on a nice summer day, so only one day is predetermined as the excursion day, where you will choose one of the combinations of culturally and professionally interesting destinations. If you are really itching for a splash in the sea, rest easy, we will be organising a beach trip as an alternative to the departure day.
And what about practical information? Zagreb is the capital of Croatia, and you can reach it quite easily by your own motor vehicle, train, bus or airplane. The main mode of transportation in the city are the ZET trams and busses,

coloured bright blue and traditionally not there in the exact moment you need one. The conference will be located a 5-minute walk from the main train station, with direct access to busses and trams – only 2 tram stops to the main square. The currency used is not Euro, instead you will be using the Croatian kuna (engl. marten), HRK, with its name following our nation's wonderful tradition of using marten pelts as a method of payment, which doesn't exactly make sense to us, either. The shops and banks are usually open until the evening every day except for Sunday, and you can easily find shops open on Sunday at the main train station, for example. The spoken language is Croatian (Slavic roots), but you can freely expect most people to be able to speak English, and all of them to trip over themselves trying to help you if there's something you need help with. The most important thing to keep in mind is that the summer in Zagreb gets very hot, so prepare accordingly!

You can find additional information on Croatia and the NC Croatia's activities in the 2013 edition of jIAPS (found on the IAPS website) or on the icps2015.unizg.hr website, and if you have any questions, feel free to contact any member of the Organising Committee (e-mail addresses listed on the ICPS 2015 website). We all love the ICPS and want to make it a great experience for everyone, so in case you have any complaints, ideas or requests for the conference, let us know through suggestions@icps2015.unizg.hr. The application period will begin on 1 February 2015 (you will able to sign up for an e-mail reminder through our website), and the conference will be held 12-19 August 2015.

In the name of the Organising Committee of the ICPS 2015 and the NC Croatia, I would like to invite you to join us in Zagreb next year, we are eagerly awaiting you!



BY IVANA KUREČIĆ
ivana@icps2015.unizg.hr

Ivana Kurečić is the president of the Organising Committee for the International Conference of Physics Students 2015. She is currently finishing her MSc at the University of Zagreb, and has an interest in all things topological and/or shiny.

ICPS 2016 - NC Hungary

The International Conference of Physics Students is organised every year by a member society of IAPS.

The Hungarian Association of Physics Students (Mafihe, NC Hungary) would be pleased to host ICPS 2016. Since the first conference was organized in Hungary in 1986 by the Mafihe, thus we would love to celebrate its 30th birthday at its birthplace: Budapest.

Since 1986 the number of the participants have increased continuously, now we would like to welcome 450 students from all around the world and involve about 50 people from Hungary as organizers.

Organizers

MAΦHE

Hungarian Association of Physics Students (Mafihe) was founded by 137 people, of whom some were also among the founders of IAPS. It has 4 local committees in 3 cities (two in Budapest, one in Debrecen and one in Szeged)

We organise scientific and cultural programs for physicists or those who have any contact to physics (not just for Hungarians: check out for example the Ortvay Competition or the Balaton Summer School)

ICPS organizers

The members of the Mafihe are very enthusiastic about organizing the ICPS'16. The organisers would be divided into committees, which would have their own tasks. We would like to set up an Organizing Committee, a Scientific Committee and a Steering Committee. There would be individual teams (with a team leader) who are responsible for Excursions, Social Events, PR, Design and Scientific Program in these Committees. There would be an ICPS Coordinator, who organize the work of the committees and would have a good grip on the whole situation. The candidate for this position is Tamás Álmos Vámi, the current President of the Mafihe.

Date

Beginning: ***Sunday, 7 August 2016***
End: ***Sunday, 14 August 2016***

Location

Hungary is a country located in Central Europe. It is part of the European Union since 2004 and Schengen since 2007. Our country is famous for the palinka, the wines of Tokaj, the Lake Balaton, the spicy foods, it's scenic cities, The Martians, it's rich folk culture, Puskás, the Rubik Cube, the Gömböc, Liszt Ferenc, the water polo team and the beautiful girls. Hungary is one of the five places in the world where the last names precede the first names. The country itself has an intricate history, which starts with the Kingdom of Hungary founded on the Christmas Eve of 1000 A.D. with the coronation of St. Stephen the First.

Budapest is the capital of Hungary. The city has about two million residents, which is the fifth of the population of the country. It is composed of two historical cities: Pest and Buda on the two sides of the Danube. Budapest is often referred as the Queen of Danube, which is crowned by eight bridges, and three islands between the two sides. We are proud of the fact that the Buda Castle Quarter, the Banks of the Danube, and the Andrássy Avenue are world heritage sites

and the mountains of Buda house many worldwide famous thermal baths.

ELTE

According to the primary plans the ICPS would take place at the Eötvös Loránd University (ELTE). The University was founded in 1635, making it the oldest Hungarian university. ELTE has more than 30000 students (of which 600 are physicist) studying on eight faculties, making the university also the biggest one in Hungary. The university is not only historical, but internationally acknowledged as well.

Accommodation

Schönherz Hostel is about five minutes walk from the lecture hall and the canteen. It has four-bedded-rooms and there are bathrooms in each room. It is important to mention that the building was fully renovated in 2009.

Conference fee & Prices

As we could see at the former conferences, the prices of the conference are student friendly. We would like to fulfill this practice at ICPS'16 as well. We would like to have a two-step registration procedure, where the fee would be the following:

Early registration fee: ***180 €***
Late registration fee: ***200 €***

Scientific Program

Plenary lectures

We would like to invite Nobel Laureates. One of our first candidate is Professor Higgs and we have already made some progress with getting contact with him. Although he has no email address, we managed to get his postal address. We will be able to reach Professor Oláh (Nobel Prize in 1979 for his contribution of carbocation chemistry), Professor Kroto (Nobel Prize in 1996 for fullerens), Professor Gross (Nobel Prize in 2004 for his contribution of the strong interaction) and Professor Geim (Nobel Prize in 2010 for graphene & Ig Nobel Prize for levitating frogs).

Some of our worldwide known scientists are also considered, such as Professor Diósi, who is known among other things for the Diósi-Penrose theory, Professor Vicsek who is working on collective motion and complex networks, Professor Lovász who is a well-know matematician (he is the current President of the Hungarian Academy of Sciences) and Professor Szemerédi, who received the Abel Prize in 2012. It would be also nice to invite someone from the Founders, that is why we considers Professor Lévai to ask.

Lab tours

We plan to organize Lab tours at the Eötvös Loránd University, at the Wigner Research Centre for Physics, at the Kármán Wind Tunnel Laboratory and many more places.

Parties

Sunday (7 Aug)
Welcome Reception – "Mad World" Party Club at the basement of the Schönherz Hostel

Monday (8 Aug)
Costume Party – "Mad World" Party Club at the basement of the Schönherz Hostel

Tuesday (9 Aug)
Free Night – I would suggest to see Budapest at night from the Buda Castle or from the Citadella, it is really beautiful.

Wednesday (10 Aug)
Spa Party – Széchenyi Spa

Thursday (11 Aug)
Hungarian Night – Party tent at the Lágymányos Campus (between the two buildings of the Eötvös Loránd University)

Friday (12 Aug)
Nations Party – Party tent at the Lágymányos Cam- pus (between the two buildings of the Eötvös Loránd University)

Saturday (13 Aug)
Farewell Party – Party tent at the Lágymányos Campus (between the two buildings of the Eötvös Loránd University)

Travel expenses

Flight prices to Budapest are depicted on the map below. These are calculated as a high estimation when you buy your tickets half a year earlier.

Excursions

Lake Balaton – Beach
Visegrád – Boat trip & City tour
Esztergom – City tour
Budapest – Labyrinth of Buda Castle
Budapest – Mátyás Caves
Rám Gorge – Outdoor Hiking

Plan B for the venue – Surprise plan

Our "Surprise plan" would be to place the Conference at Csillebérc, at Wigner Research Centre for Physics. In that case we would get the Lecture Halls for free, the meals would be cheaper and be held at the same building. According to the plans this building will be declared open in 2015, therefore the ICPS would be one of the first big conferences there. Actually, the conference will take place here with good chances. But Plan A for the venue works for sure as a backup plan.

Venue

The accommodation would be very close to the Wigner RCP. The Youth Centre & Hostel at Csillebérc is a huge area, where there are leisure facilities, sport opportunities, swimming-pool and of course the accommodations.

Conclusion

All in all, in this case the venues would be held in a much smaller area and the prices would be lower. On the other hand, Csillebérc is located in the outer part of Budapest, so it would take about 30 minutes to reach the city center. The rest of the details would be the same as written in Plan A.

Tamás Álmos Vámi studies Physics at the Eötvös Loránd University, Budapest. He has been elected for the President of the Hungarian Association of Physics Students last year. He experienced being in the leadership of an association, as he was the Head of the Scientific Department and in the following year the Coordinator of Hungarian Student Research Association (KutDiák). At this KutDiák Association he skilled the challenging tasks of organizing conferences and the beauty of dealing with many people. Since, he is working at the Wigner RCP, he participated in several international conferences as well.

BY TAMÁS ÁLMOS VÁMI
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IAPS Members '13/14

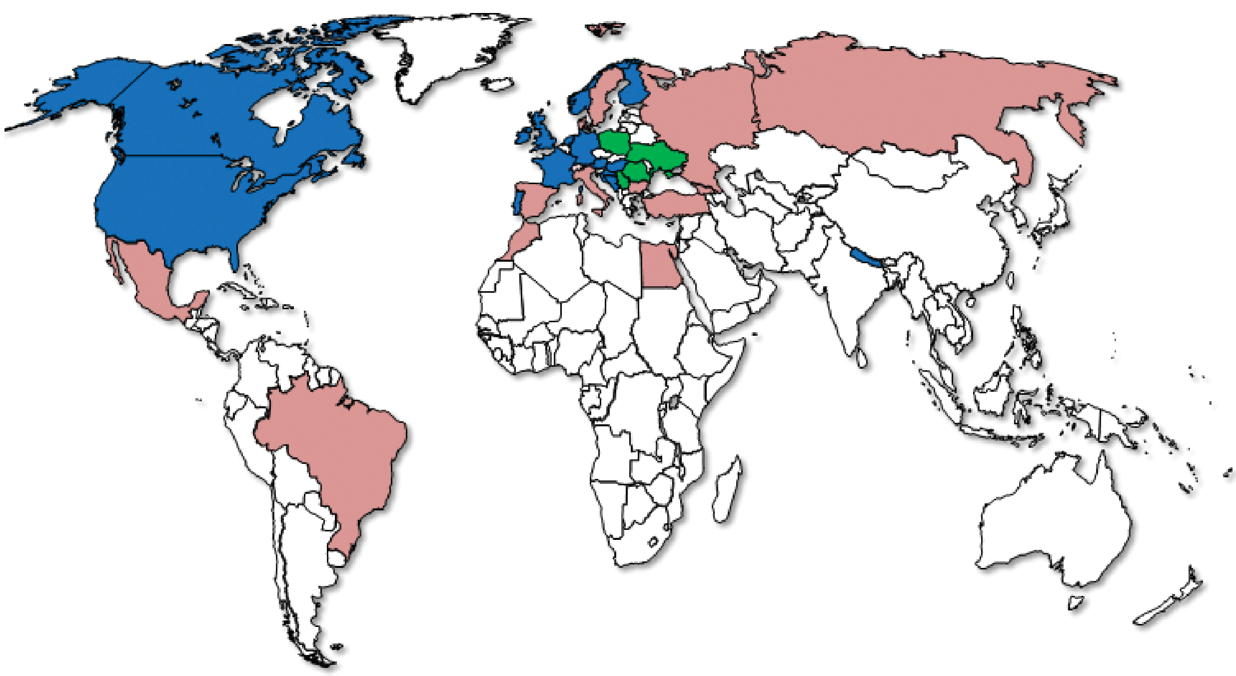
Since the founding of IAPS in 1986, the member landscape has changed significantly. Where we started out with three national committees inside of Europe, the association now exists out of 14 national committees, 8 local committees and around the 400 (provisional) individual members from 28 different countries as can be seen in the map below.

Map of IAPS members
Pink - (provisional) individual member
Green - Local Committee (LC)
Blue - National Committee (NC)

Map of Local Groups in Europe
Most of the NC's have their own Local Groups (LG) who also are represented by IAPS, in the map to the right you can see how the 128 LG and LC's are spread out over Europe. In North America there are over 700 LG's present, which set the count of LG's on approximately 830!

As shown IAPS has expanded quite a lot in the past years and also this year there are one new NC and two new LC's who have said that they are committed to join the international association of physics students.

IAPS is looking for its individual members in Europe to create NC's / LC's or to find an association that can function as one to increase the participation of all regions and to establish a stable form of communication. Also outside of Europe IAPS is looking for committees to join IAPS and participate in, and organize IAPS events.



The quest for a unified theory: why quantum gravity still proves to be elusive to modern day physicists

'… [the] vision of the universe arranged in harmonies of sounds and relations is no new discovery. Today, physicists are simply proving that what we call an object… an atom, a molecule, a particle, is only an approximation, a metaphor. At the subatomic level, it dissolves into a series of interconnections like chords of music. It's beautiful.'

'Yeah, but there are boundaries, aren't there? I mean, between you and me, for instance. We are two separate bodies, aren't we? That's not an illusion. Is it? Are you saying that there is a physical connection… between you and me, and you and the wall behind you… and the air and this bench?'

'Yes. At the subatomic level there is a continual exchange of matter and energy between my hand and this wood, between the wood and the air, and even between you and me. I mean a real exchange of photons and electrons.

Ultimately, whether we like it or not… we're all part of one inseparable web of relationships.'

[Mindwalk, Bernt Capra]

A brief insight into the historical aspect of the modern physics

'In these days of conflict between ancient and modern studies, there must surely be something to be said for a study which did not begin with Pythagoras and will not end with Einstein, but is the oldest and youngest of all.'

[A Mathematician's Apology, G.H.Hardy]

The idea of the atom was long forecasted by a few Ancient Greek philosophers, amongst them Leucippus and his student Democritus. Yet it was vehemently criticized by several European scientists in the mid-19th century. Boltzmann suffered ostracization from the scientific community for trying to reintroduce this concept as the basis of all matter, which ironically we hold as a pretty conventional notion these days. There is a tendency in the scientific world for old ideas to be regenerated and surface under various forms in distinct time frames, or in other words, to be repeated. Indeed, most great insights tend to be provoked through previous reflections upon some inspiring work!

For instance when Einstein attempted to understand the problem with Maxwell's equations and Galilean transformations, he soon realized that essentially Galileo's intuition concerning the notion that velocity is only relative and inertial systems are equivalent could not be wrong. Yet Maxwell's insight that any interaction is mediated by a field could not be incorrect either. Still, there was difficulty in putting the two together because it was thought that one was of limited validity in terms of the other and thus not equivalent. The seeming contradiction rested upon the fact that physicists were subconsciously taking an incorrect assumption in their deductions. Einstein's wonderful contribution was in amending the wrong assumption that simultaneity was well defined. The history of physics is riddled with instances where a scientist discerns an erroneous hypothesis in merging two theories together so as to account for both of them (sometimes by borrowing from yet another theory).

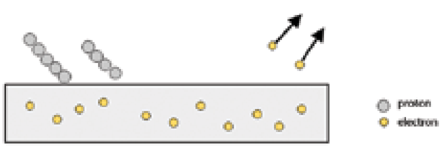
Maxwell's dream of Unification extended

"I have long held an opinion," says that illustrious experimentalist, "almost amounting to a conviction, in common, I believe, with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin; or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, into one another, and possess equivalents of power in their action."

[Vril, The Power of the Coming Race, Sir Edward Burton-Lytton]

Near the turn of the 19th century, it was widely held that the great problems in physics had been solved and what was left to decode were a few details. One of these 'details' was known as the ultraviolet catastrophe, which emerged from applications of statistical physics to complicated systems, such as energy distribution among different frequencies in blackbody radiation. A blackbody is one that perfectly absorbs all incident radiation and then releases all of that radiation. The puzzle was essentially a product of friction between the theoretical predictions and empirical observation; it was predicted that an infinite amount of energy was concentrated at the highest frequency yet this was not observed experimentally. A curious reassigning of this problem by Max Planck explained the seeming dichotomy. He discarded the assumption of classical physics that energy radiated continuously in and out of the black-body and instead suggested that radiation was emitted (or absorbed) in discrete energy packets called quanta, whose energy content is proportional to the frequency of radiation where the constant of proportionality was taken to be a universal constant of nature, today widely known as Planck's constant.

The idea of quanta was explored further by then a young patent clerk, Albert Einstein, while pondering about yet another unresolved mystery, the photoelectric effect. Einstein noticed that if one had to consider the light ray as a beam of persisting quanta, the apparent mystery would vanish due to Planck's claim. The collision of a photon with the metal surface would result in the emission of an electron from the surface only if the original photon exceeded a certain frequency (threshold frequency). Such discoveries were just the beginning of a truly wonderful era.



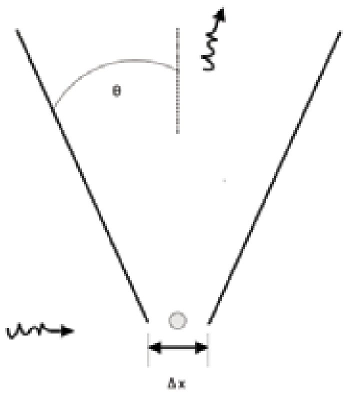
Light-matter interaction: the photoelectric effect

The weirdness of Quantum Mechanics

'A red dragonfly hovers above a backwater of the stream, its wings moving so fast that the eye sees not wings in movement but a probability distribution of where the wings might be, like electron orbitals: a quantum-mechanical effect that maybe explains why the insect can apparently teleport from one place to another, disappearing from one point and reappearing a couple of meters away, without seeming to pass through the space in between.'

[Cryptonomicon, Neal Stephenson]

As the physicists probed deeper into the nature of the atom to discover the behaviour of particles at the subatomic level, they discovered some really strange affairs which seemed to contradict all intuition. One of the very first experiments with bizarre outcomes was the double-slit experiment, which in terms of classical behaviour could be explained as the particle behaving both as a particle and as a wave. Amongst the other uncanny outcomes of quantum mechanics was Heisenberg's Uncertainty Principle, which describes the fuzziness involved when trying to detect the momentum of a particle at a specific position simultaneously. Such inherent probabilistic computations relates to the measurement problem which is beyond the fact that scientists use classical equipment to evaluate microscopic phenomena.



Heisenberg's Uncertainty Principle depicted: one cannot accurately measure the position and momentum of a particle simultaneously

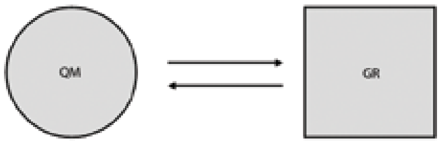
One may ask: but how can it be that the discrete nature of energy levels in the quantum world is to be reconciled with the continuous temperament of the macroscopic world? The bizarre world of quantum mechanics has been considered profoundly shocking even to the physicist, let alone to the layman. But perhaps this is only because as humans, we are embedded in a three dimensional macroscopic framework and unfamiliar with the Planck scale of quantum particles. Thus arises the confusion in language and misconceptions of ideas, like the wave-particle duality, the thought experiment of Schrödinger's cat and the EPR paradox as a corollary of the Copenhagen interpretation. There is also a whole mesh of confusion over the divergent interpretations of QM.

The puzzle of Quantum Gravity: towards a paradigm shift?

'…what we really should be discussing is 'the interpretation of classical mechanics' – that is, how can the classical world we see – which is only an approximation of the underlying reality, which in turn is quantum mechanical in nature – be understood in terms of the proper quantum mechanical variables? If we insist on interpreting quantum mechanical phenomena in terms of classical concepts, we will inevitably encounter phenomena that seem paradoxical, or impossible.'

[The Physics of Star Trek, Lawrence Krauss]

The problem at hand necessarily translates to the fact that the formalisms of Quantum Mechanics and General Relativity are incompatible with each other: QM is expressed using an external time variable which is discordant with GR since the latter did not appeal to the Newtonian mechanistic concept of time. Newton held that the flow of time was the same for all. Indeed, one of the triumphs of relativity was its illustration that the passage of time was not the same for all observers but depends upon the velocity of the subject; the difference would essentially be negligible from Newtonian applications at very small speeds. In GR, objects are not localized with respect to some temporal or spatial frame of reference (there is no fixed background structure). Localization is only with respect to the field and not with respect to some arbitrary coordinate system. On the other hand, in QM the dynamical field is quantized and also follows probabilistic superposition states. The question thus is: How can we fully describe quantum spacetime?



To simplify this train of thought, we need to change the coordinates or limits of GR to fit those defined in QM (or vice versa), that is, for the frames of reference to match and thus the two theories may become isomorphic (equivalent) to each other. One approach to this is to localize the process (spacetime region) by having states in a boundary associated with amplitude instead of considering the boundaries at asymptotic infinity!

Exploring Quantum Gravity: reconsidering the notion of gravity

'Everything in our past experience tells us that the two descriptions of Nature we currently use must be approximations, special cases which arise as suitable limits of a single, universal theory. That theory must be based on a synthesis of the basic principles of general relativity and quantum mechanics.

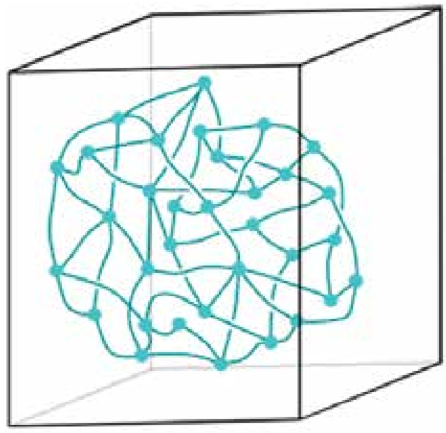
This would be the quantum theory of gravity that we are seeking.'

[The Ashgate Companion to Contemporary Philosophy of Physics, Abhay Ashtekar]

The pursuit of quantum gravity is mainly split into three main lines of research, known as covariant, canonical and sum over histories. The initial investigation route was the construction of Quantum Field Theory by considering the metric fluctuations over a flat Minkowski space (since this is the metric space we most conveniently use for relativistic considerations), which eventually led to string theory. A consequence of this theory is the multiverse, where the initial conception of our universe would not be described by a cosmic inflation from seemingly nothingness (big bang), but rather the fusion of two universes into one or a universe's separation into two baby universes. The big dilemma about this theory is that there aren't testable predictions which can be verified, so despite the fact that theoretically it satisfies the unification of QM and GR, we do not yet know if it gives us a description of the physical universe even at extreme situations like the singularity of a black hole.

The canonical research involved in developing a quantum gravity theory was based directly on Einstein's geometrical formulation, known as Loop Quantum Gravity. In this theory, one can regard space as a fine network of finite loops so that the structure of spacetime is discrete. But unlike string theory, LQG makes some definite predictions, which implies it may well be tested before string theory is. The cosmological implications of this theory is that there is no big bang singularity; instead, the universe's history can be traced far into the past in an infinite regress known as the Big Bounce.

The sum over histories inquiry (or path integral formalism) comprises Feynman's ideas and Hawking's mostly through Euclidean quantum gravity. There is still much unfinished work in this approach. Also, there have been other ideas working alongside these three principal ones, but so far none of them have been developed into a full theory of quantum gravity. Peter Bergmann, one of Einstein's collaborators, had this to say during the 1963 *Conférence internationale sur les théories relativistes de la gravitation*,



Spin network to represent interactions between particles [6]

'In view of the great difficulties of this program, I consider it a very positive thing that so many different approaches are being brought to bear on the problem. To be sure, the approaches we hope, will converge to one goal.'

Although the vogue in physics has been to understand gravity at the atomic level, one should apprehend that some concepts used to describe the natural world would be deficient on different scales, for instance water is wet but its molecules would not be described as such. Just because a theory makes fairly accurate predictions for atoms for instance, this does not imply that we can extend this theory to apply to the planetary scale. The same pertains to gravity; we perceive the effects of gravity acting on masses, but is it indeed present on the atomic scale? Can we measure the 'curvature of spacetime' inflicted by a pair of atoms? In this sense, it would be considered as an emergent phenomenon. Erik Verlinde, who has been working on a new theory of gravity, harbours such ideas. So that instead of gathering information on the behaviour of every specific particle – which would be impossible because of the uncertainty involved – one can study the behaviour of the entire gas or system as a whole.

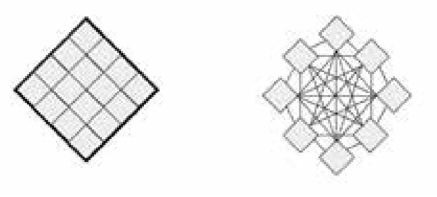
Reconsidering the pursuit for a grand unified theory

'We often think that when we have completed our study of one we know all about two, because 'two' is 'one and one'. We forget that we have still to make a study of 'and'.'
[unknown source, Arthur Eddington]

The rapid accumulation of scientific knowledge in the last few centuries can be accounted for because of specialization – detailed analysis of a specific area of study. However, efforts are being generated towards a unification of ideas, synthesizing these discrete branches of physics into an integrated whole. Although this endeavour is to be highly esteemed, one must claim that such efforts would be prolonged unless one reflects on the problem at hand thoroughly. One question which still remains unanswered is: Are the four fundamental forces simply different aspects of one fundamental entity, in the same fashion that electricity and magnetism turned out to be manifestations of the same one spectacle?

Another curious mystery is the fact that gravity is so much weaker than the other three forces, namely the weak force, the strong force and electromagnetic force. Nonetheless, the Standard Model has not been able to account for gravity at the smallest of scales; although a new particle graviton has been hypothesized to account for gravitation, this has not been found yet despite countless experimentation. The other forces have already been integrated through the Standard Model, though gravitation eludes us still on the microscopic level.

Finally, the definition of everything as provided by the Oxford Dictionary of English incorporates 'all things' whereas current physics is concerned only with the ordinary universe, which amounts to 4.9% of the total mass-energy of the known universe. Although these claims seem to verge on the pessimistic, they need to be taken into consideration if we are to find a true generic understanding of the world.



If the outer boundary encloses all the edifice of physics, and the inner shapes the specific branches of physics, can we really claim our current knowledge suffices to be able to construct a theory of everything? A very optimistic guess would be that our current knowledge only takes up 1/16 of the rest yet to be discovered, which is very little when one considers the great efforts towards combining all of physics into one single theory.
In the second figure, I have attempted to outline very arbitrarily the connections we still need to discover before we reconcile our efforts towards a Grand Unified Theory. For instance, the energy- mass equivalence is only one such relation between two previously distinct phenomena. For sake of clarity, I had to reduce the original number of shapes (which represent the physics branches) to make the analogy clearer in the allowed space.

Notation

Although it is pretty clear, I declare these acronyms for those reading the article and are unfamiliar with certain notation;

QM: Quantum Mechanics, GR: General Relativity, LQG: Loop Quantum Gravity

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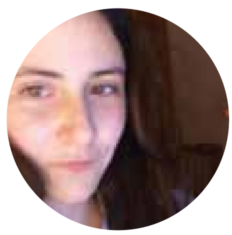
Anna is currently studying physics and mathematics at the University of Malta. She is very enthusiastic to understand the natural world and is amazed with its complexity, reading up from encyclopedias to learn more about humanity's place in the cosmos. Aside from her general interest in science, she is also very keen on science fiction, etymology and mythology.



BY ANNA FAVA
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Quantum meets Cryptography: How physics can help save our secrets

When one hears about Quantum Cryptography, the first thought that comes to mind is, how can there be any relation between physics and codes? It actually appears to be one of the newest ideas in the cipher world to use physics and has been declared as the ultimate goal in security. In this short introductory text we will try to explain how these two, from first sight totally unrelated things fit together, how quantum cryptography works and what makes it so secure, and therefore important.

What is Cryptography?

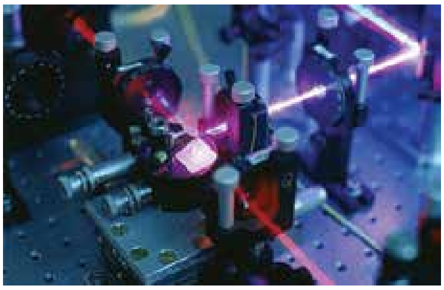
Classical cryptography was always about constructing and analysing protocols in order to protect information against the influence of adversaries. Modern cryptography is composed of disciplines such as mathematics, computer science and electrical engineering. All it needs to ensure is the creation of a safe, complex and indecipherable code to third parties. With secret key cryptography, a single key is used for encryption and decryption. The sender uses the key to encrypt the plain text and sends it to the receiver. The receiver applies the same key to decrypt the message and recover the plain text. Cryptography includes everyday things like computer passwords, ATM cards, electronic commerce and much more. All of the current day classical computer cryptography are based on certain class of mathematical operations that are easy to perform in one direction but are extremely difficult in the opposite direction. Example of such a problem is prime number multiplication. It is very easy to multiply two prime numbers of any length (one direction). However, if you are given a long two million digits number and told that this number is a product of two primes, even with the help of modern computers it would take hundreds of years to find its constitutes-prime factors. This is the basis for the well known RSA (Rivest-Shamir-Adleman, 1977) cryptosystem [1], the importance of which is obvious since nowadays the internet is used by and provides essential communication between hundreds of millions of people.

New Age Methods

Differently from the classical version of cryptography which uses key, based on the assumption that there are no sufficiently fast mathematical algorithms for deciphering, quantum version of cryptography is based purely on the laws of quantum physics. Currently for deciphering, mathematical algorithms are based on computing power and brute force methods. Usually this kind of deciphering is not worth anything, since user can change the key frequently enough, so as to not to give enough time for decipherers to decrypt the key. If one decides to use faster computers and more advanced methods for decryption, another can just simply increase the length of the key used for encryption. When the idea of quantum computing became omnipresent, it soon became obvious that quantum computers could provide unprecedented ability to encrypt secret information. With the use of quantum, it is possible to create devices which allow detection of whether data transmission channel is being spied. Devices which are based on quantum physics phenomena, usually use one of the following: Heisenberg's uncertainty principle or quantum entanglement. In its modern form, the Uncertainty Principle tells that the measurement process itself is a part of physical system, and not a passive process, like it is in classical version of physics. The Uncertainty Principle implies that there exist such properties of particles which are not possible to measure exactly at the same time: measurement of one property will inevitably disturb the measurement of the other. Entanglement, on the other hand is a superposition of two or more particles when their states correlate. Entangled particles cannot be described by the use of states of individual particle. This can be used to exchange information in a way that cannot be seen when experimenting with single particle. Entanglement can be observed independently of how far particles are from one another. Based on these two phenomena, several quantum cryptography protocols were created. In the first method, bits of information are coded based on the polarization of photon and on the use of the Uncertainty Principle to try to prevent the eavesdropper (known as Eve) to steal and decipher the information. The second method uses entangled states of photon, and information is revealed only when the state of a photon is measured by Alice (sender) and Bob (receiver) [2]. The correlation of quantum entanglement can not be explained simply using the concepts of classical physics.

Quantum version of cryptography is based purely on the laws of quantum physics [4]

Examples



Every type of polarization can code one bit of information [5]

Quantum cryptography systems are safe against "Man-in-the-middle" attacks [6]

Scheme of quantum cryptography known as BB84 protocol (Bennet&Brassard, 1984)[3], uses pulses of polarised light. Two types of polarisation are used: linear and circular. Linearly polarised light can be vertically or horizontally polarised, whereas circularly polarised light can be left or right handed. Every type of polarisation can code one bit of information, for example horizontal polarisation := 1, left handed := 1, vertical := 0, right handed := 0. To generate a key, random sequence of vertically (or left handed) and horizontally (or right handed) light is sent through a channel with an equal probability in order to mislead a spy. Simple quantum cryptography protocol can be described as follows: 1. Light source creates light pulses of very low intensity. Then, Alice (sender) modulates polarization of these light pulses in a random order of one to four possible states described above. 2. Bob (receiver) measures polarization of photons received in a randomly selected bases (linear or circular). Here it should be noted that quantum systems are very fragile by their nature. Therefore Bob has only one chance to perform a measurement before a quantum state is destroyed. Investigation of non-destructive quantum state measurement techniques is currently very wide field, and in the future could have huge benefits in quantum cryptography. 3. Bob publicly announces what was the sequence of his bases used for measurements. 4. Alice publicly announces which bases were chosen successfully and are the same as sent by her when modulating light pulses. 5. Alice and Bob disregards results of incorrectly chosen bases. 6. Results are interpreted using binary system: horizontal or left handed polarization corresponds to 1, vertical or right handed polarization corresponds to 0. Entangled pairs scheme uses entangled states of photons. These photons can be generated by Alice, Bob and Eve. However, in any case photons should be distributed in such a way that Alice and Bob have one photon from each pair generated. Ideally correlated states can be created, such that when measuring polarization of correlated states Alice and Bob always get the opposite values. On the other hand, when measuring individually, result is always random: it is not possible to predict what will be the polarization of the next photon. These states have what is known as a non-locality property. Non-locality property does not have an analogue in classical physics. During communication, the results of measurements of states by Alice and Bob will correlate at some level, and if Eve tries to disrupt their connection she will disrupt the correlation, which can be easily detected. In other words quantum cryptography systems are safe against "Man-in-the-middle" attacks. Specifically, a pair of entangled photons has opposite rotational directions or spin states with the total spin of the system being zero. The important implication of this property is that the measurement of spin of one immediately gives the spin of the other. The measurement of any measurable property of a photon disturbs its state. This is the measurement problem. However, this fact provides the advantage that the presence of an eavesdropper can be detected.

Conclusions

Quantum computing has become a reality. And even though it is still in its infancy, there is already a threat of using classical cryptographic coding schemes because quantum tools could be able to quickly crack almost any code. In order to avoid this, we need new breakthroughs, new cryptography ideas, new tools. Quantum cryptography sounds like a solution. Currently there already exist few companies selling quantum key distribution systems, examples include IDQuantique and MagiQ. This type of technique provides a possibility of extremely safe data transmission, as well as avoiding any influence of third parties because the interference can not be overlooked and "Man-in-the-middle" attacks can be prevented. Seemingly it is fair to say that quantum future will bring us new, safer and more reliable tools for protecting our secrets and all this would be impossible without physics.

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BY TADAS BARTULEVICIUS & DEIVIDAS SABONIS

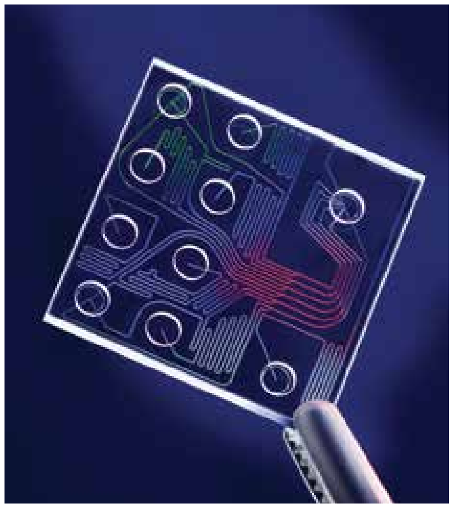
OPTOFLUIDICS: MERGING LIGHT AND WATER

The term Optofluidics was for the first time coined in 2003. Currently it is defined as a very rapidly emerging research field the main focus of which is combining microfluidics and optical technology. If we look back, in the last 5 years this terminology has become widely adopted for a large number of research directions. It is easy to check this because currently the input of the term "optofluidics" in Google search now yields more than 30,000 results. It early became apparent that the concept of optofluidics, to take the idea of combining the advantages of microfluidics and optics could bring much more to both of these fields than they are separately. Some of the projects for which links between the birth of the term optofluidics and the initiation of the projects exists are for example the optofluidic microscope and optofluidic lasers.

This leads to the question: What exactly is optofluidics? In this short article we will address and try to answer this question. Here we will also try to briefly examine the advantages of optics and microfluidics, discuss some of the ways these two disciplines can combine, and how the combination can lead to and generate optofluidic technologies with unique capabilities.

What is Optofluidics?

In 2007 a review paper [2] was released which started the shift to a more systematic definition of optofluidics in which the advantages of optofluidic technologies were discussed as well as possible benefits to both the optics and the microfluidics fields. In the present context, optofluidics can be defined as the combination of optics and microfluidics in the same platform to use specific advantages of these two disciplines. Optofluidics brought us new and potentially more useful and better ways to build and use already well established optical technologies, structures and devices. It is also fair to say that some of the growth directions in recent years have also been totally unanticipated.



Example of the optofluidic circuit (lab on a chip device) [3]

Advantages

As mentioned above gave us a new way to think about either optics and fluidics. At the moment, key advantages of optofluidics are:

1. The ability to change the optical properties of the fluid medium within a device by replacing one fluid with another.

2. Immiscible fluid-fluid interfaces are smooth. It has been known for a very long time that the optical smoothness of fluid interfaces can be very useful property for various applications. For example it could provide a cost-effective way to create optical surfaces. This happens due to surface tension, and as a result – an immiscible fluid-fluid interface is uniform and smooth.

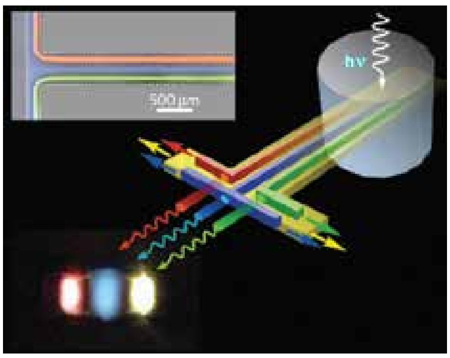
3. Diffusion can create controllable blend of optical properties. This property is of extreme importance for various applications. The solid-based structures fail to provide this property that can be created by the diffusion across the interface of two liquids. Flow parameters, fluid choices, and the device structures can be tuned in such a way as to provide full controllability and flexibility and enable the creation of novel optical interconnects. For example, an optical splitter and wavelength filter based on the selective mixing of two fluid jets in a third fluidic medium has been demonstrated recently. This differs from a conventional beamsplitter because the split ratio of the optofluidics based beamsplitter can be dynamically tuned for any given wavelength.

4. Fluid can act as an excellent transport medium. This is so because it is relatively easy to input, move, and manipulate fluid in an optofluidic device. As in previous example pressure differential is a common and convenient property to achieve this. One of such examples of optofluidic technology that makes good use of fluid transport is the optofluidic mask-less lithography approach.

5. Optofluidics could also help to build optofluidic lasers, the working principle of which depends on the switching of laser dye medium as a way to achieve wavelength tuning over the range of interest.

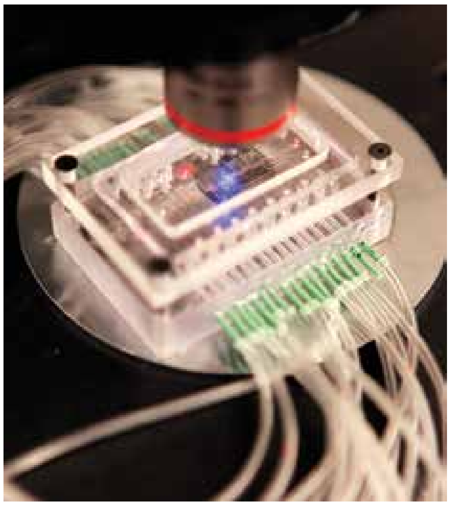
6. Last but not least is that fluid can be an excellent buoyancy mediator. The density of fluid media ranges widely. By mixing two miscible fluids, fluid with arbitrary intermediate density values can be created.

Although not mentioned above, recently, there has also been a significant progress made in the use of wave-guides to exert new types of controls. Beyond direct force use, like momentum transfer, there are other but more subtle ways in which light can be used to manipulate and move fluids and objects in fluids. This can be achieved with the use of optically induced heating and fluid vaporisation. These phenomena act in a way that helps to manipulate fluid in totally new ways and therefore show significant advantages of optofluidics technology. We can therefore, reasonably expect and anticipate rapid growth of this field during coming decades at an increasing pace.



Optofluidics can provide us with a controllable blend of optical properties [4]

Conclusions



Optofluidic microscope [5]

As described in this short article, the field of optofluidics emerged from a series of efforts in trying to fuse advanced planar optics with micro and nanofluidics. One of the current aims of this new and rapidly emerging field is the development of optical devices that have new functionalities enabled by microfluidic elements. Main advantages of these devices are associated with their ability to exploit various old and new fluidic transport phenomena. This is in order to change optical properties like refractive index, gain, and non-linearity, over very small length scales.

The opposite is of course also possible and already used, that is optical effects can be used to enhance microfluidic transport. Such techniques range from traditional optical tweezing, rotational manipulation of components of fluid to more recent electro-optic approaches where electro optical phenomena come into play. Optofluidics will find a lot of different applications in the field of biomedicine, and especially in biomedical analysis devices. This is so because of precision with which particles or fluids can be transported and separated with these optical techniques. We believe that the field of optofluidics will continue to surprise us with its new and unique devices and techniques.

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by Ajmal Faizi & Deividas Sabonis

The future of particle physics after the LHC: Compact Linear Collider

When the LHC was about to be launched they said that "the future is here". Now the biggest accelerator in history has successfully finished its first run and the discovery of the Higgs boson was announced. The era of LHC and its discoveries has just begun and it has another two or even more decades of the cutting-edge science research hidden in it. A three years of the LHC run was enough for scientists to declare the Higgs boson discovery but it took almost 20 years to develop and establish it. While CERN engineers are currently upgrading LHC equipment for the upcoming run of highest energies, it is time to think about the next steps. What is the possible accelerator of the high energy experiments of the future?

Scientists all around the world are designing possible candidates for the future frontier of particle physics to enable the replacement of the largest and the most expensive machine mankind has ever built – the LHC. Before scientists can decide what project to push forward, the technologies and physics behind the various acceleration and detection options have to be understood. The upcoming choice of the global scientific community relies on the type of the future headliner accelerator (linear or circular) and also on the type of the colliding particles (protons, electrons and positrons, i.e. leptons, or muons).

Circular or linear?

One of the ideas is to upgrade the known and trustful LHC technology to far higher energies of proton-proton collisions either by building the circular 80-km-long accelerator ring (in comparison with the 17-km-long LHC) or by switching the LHC magnets to more powerful ones. Larger ring and more powerful magnets would yield much higher collision energies of about 80 to 100 TeV, and possibly lead to many more new massive particles. On the other hand, building such a massive machine and manufacturing such powerful magnets would be technically and financially problematic.

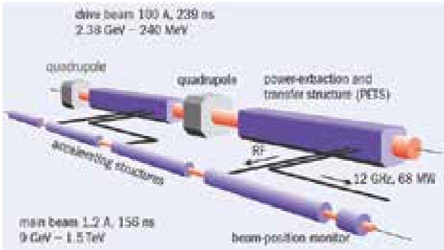
Another idea is to switch to a high-energy electron-positron collider. It is commonly believed that this is the best option to compliment and to extend the LHC physics programme. However, it is rather tricky to accelerate such light particles in a ring collider, because of the synchrotron radiation it produces when accelerated within a circular trajectory. The electron making circles would quickly lose most of its energy. When operate with leptons at very high energies, a linear collider makes more sense. The basic principle of linear collider relies on two linear accelerators (linacs) accelerating positrons or electrons in an opposite direction so that the two beams can collide at some interaction point. On the other hand, a linear collider would produce fewer collisions than a circular one. But in prospect even high energies could be achieved with linear accelerators if some technique would be developed enough and proved to work.

An example of such a technique which has been in development phase during the last decade is the Compact Linear Collider (CLIC) concept. The CLIC studies are interesting and promising due to the innovativeness of its concept which potentially could have a variety of applications and could be a great leap for the linear accelerators of the future. Now, let us explore what actually makes the CLIC technique so unique?

What are the key features of CLIC concept?

Compact Linear Collider relies upon a two-beam-acceleration concept. The Compact Linear Collider (CLIC) study is an international collaboration working on a concept for a machine to collide electrons and positrons (antielectrons) head-on at energies up to several Tera Electron Volts (TeV). This energy range is similar to the LHC's, but using electrons and their antiparticles rather than protons, physicists will gain a different perspective on the underlying physics.

The key feature of CLIC is how to provide the electromagnetic fields that accelerate the electrons and positrons it collides. In conventional linear accelerators, the radio frequency(RF) power for the main beam acceleration is generated by klystrons, electron tubes used to amplify or generate ultra-high frequency. To achieve the multi-TEV energies needed for particle physics purposes, the high-energy electric fields with accelerating gradient of >100 MVm are required. Such high gradients are easier to achieve at higher RF frequencies since, for a given gradient, the maximum power the device can withstand would be larger than at low frequencies. This fact makes it nearly impossible to use the klystrons technique of conventional linacs. First of all, the production of highly efficient klystrons is very difficult at high frequency. Secondly, the use of a large number of active RF elements, e.g. klystrons or modulators, in the main linac highly increases the length of linear accelerator. These problems could be avoided by the two-beam approach of CLIC.



CLIC: two beam scheme

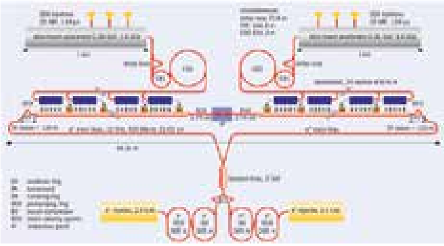
In the CLIC scheme, two beams run parallel to each other as shown on the picture above: the main beam to be accelerated, and the drive beam to provide the power for the accelerating structures. The drive beam contains many particles at low frequencies, which makes operating with klystrons easier with the low energy (2.38 GeV). Particles from the drive beam are then transferred to the main beam by a specially designed exchanger. And this transfer indeed accelerates the high-energy, low-current main beam, which is later focused and brought into collision. But let's take a closer look at particle physics magic that happens during the transfer between two beams.

How is the power transferred?

The drive beam starts its life as a long chain of electron bunches with a large bunch spacing. Those are accelerated by conventional klystron amplifiers at 1GHz frequency to an energy of 2.38 GeV. The energy of the beam at this stage is already high enough to accelerate the main beam pulse but the current of the drive beam is still an issue. In order to get the high RF power for the main beam accelerating structures the current of the drive beam has to be increased from 4.2 A to 100 A. This could be done in a sequence of three rings: the delay loop and two combiner rings where the intensity and frequency of the drive beam bunches are magnified.

When the energy and the current of a drive beam are sufficient, the RF power can be provided to accelerate the main beam by decelerating the drive beam. The decelerator complex consists of 625 m long units. In order to achieve energy of 3 TeV the amount of 2 x 22 units is required for a total linear accelerator length of ~ 28 km. Each unit contains of 500 "Power Extraction and Transfer Structures", PETS, feeding 1000 accelerating structures. Through PETS, the RF power is transferred to the main beam. The bunches of the drive beam that pass through PETS interact with the impedance of periodically loaded wave-guides. In this interaction process, the beam kinetic energy converts into the electromagnetic energy at the mode frequency, which travels along the structure with the mode group velocity. This RF energy is then sent from the PETS via rectangular wave-guides to the accelerator structures in the parallel main beam. One PETS with a different design has already been tested to produce 30 GHz of RF power. This is how the deceleration process of one beam is used to accelerate another.

What happens in the main beam complex?



CLIC complex

Once the RF power is extracted from a drive beam it is used for accelerating two main beams of electrons and positrons facing each other, so that two beams of particles can collide head on. The problem here is that in linear accelerators the beams collision happens only once, so very high luminosity is demanded. In order to obtain the required high luminosity, the beams have to have extremely small emittance, ie the average spread of particle coordinates in position-and-momentum phase space at the collision point. At CLIC, two damping rings in succession will provide the necessary reduction in each of the main beams. In the main linac itself, the RF accelerating structures are used to control the wake fields induced by the bunches to avoid the emittance bloat. Finally, a sophisticated beam-delivery system consists of the quadrupoles which focus the beam down to dimensions of 1 nm RMS size in the vertical plane and 40 nm in the horizontal. After the focusing, two beams are brought into collision and from there on the detector system is responsible for catching physics this collision is underlying.

CLIC perspectives

The Higgs boson discovery brings in the questions about the nature of this particle: is it a fundamental particle or a composite? Is it a part of a more complicated electroweak sector? Does it universally couple to all the matter proportionally to its mass? The LHC can only partially answer these questions. The CLIC can explore thoroughly the TeV region of these issues in much greater depth and address these questions by measuring the Higgs couplings to a very high precision.

Another issue is the super-symmetry theory studies. Super-symmetry is often considered an attractive option to deal with the naturalness problem of the Higgs boson. If supersymmetry indeed lies near the weak scale, the LHC is bound to discover it. But it's clear that LHC is unable to resolve all questions related to supersymmetry. Heavy sleptons, neutralinos and charginos can only be produced copiously at the LHC through decay chains of strongly-interacting supersymmetric particles and, in some cases, these chains do not access all states. But the TeV region of CLIC allows to look for any new particles with electroweak charges. The precise mass and coupling measurements that can be performed at CLIC are crucial to address fundamental questions about the mechanism of supersymmetry breaking, about aspects of unification, and about the viability of the lightest supersymmetric particle as a dark matter thermal relic.

In conclusion

The two-beam idea of the CLIC is innovative and unique but as a possible accelerator of the future it faces a lot of designing issues. All of the aforementioned CLIC features must be approved to work on a massive scale of 30 or 40 km. Many of the key aspects of the CLIC scheme have been experimentally validated already in different test facilities (CTF, CTF2 and CTF3). But there are still many more stages in research and development before a feasible technical design report could be published and a Compact Linear Collider could become real. Today, it is hard to say what the post-LHC future of particle physics will be. But we know for sure that for the next 20 years LHC is going to be a top-priority of the front-page science. According to the CERN scientists, any decision to start a new generation machine construction would have to be made by the end of this decade, as it might take another decade or even two to actually build the structure. From all these statements it can be concluded that only time will show whether or not the CLIC will become the next most powerful mankind machine.

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Theory of Almost Everything: The Standard Model and its imperfections

The Standard Model of particle physics (SM) is a theoretical framework which unifies the electromagnetic, weak, and strong nuclear interactions. They have the most important role in the world of the elementary particles known by mankind. As the parts of the SM we can mention two very important theories:

a) Electroweak theory. This is the unification of the weak and electromagnetic interaction between the elementary particles. This theory was elaborated by Abdus Salam, Sheldon Glashow and Steven Weinberg in the latter half of the 20th century. In appreciation of their work they got the Nobel Prize in Physics in 1979. [1]

b) Quantum chromodynamics (QCD). The QCD is a theory of strong interactions, a fundamental force describing the interactions between quarks and gluons which make up hadrons (such as protons and neutrons, see more detailed description later). David J. Gross, H. David Politzer and Frank Wilczek were rewarded with the Nobel Prize in 2004 for recognizing one of the consequences of the QCD. [2]

Most physicists' main object in life is to find the ultimate theory that would unite all of these theories into one integrated theory of everything. In that case, all the other known laws would be special cases of this ultimate theory, and the behaviour of all kinds of matter and energy could be derived from it. The Standard Model, of course, is not the ultimate theory, it has imperfections, for example gravitational interactions are left out from it. Still the SM is an amazing achievement, which describes almost everything we know about matter and its interactions. This is why the Standard Model is sometimes regarded as a "theory of almost everything" [3]

Types of particles

The elementary particles are classified according to specific aspects.

Classification according to spin

The most important one is classification according to spin. Particles with half-integer spins, such as 1/2, 3/2, 5/2, are known as fermions, while particles with integer spins, such as 1, 2, 3 are known as bosons. (Figure 1.)

A principal difference between the two families is that fermions obey the Pauli exclusion principle, however bosons do not. According to the principle there cannot be two identical fermions simultaneously having the same quantum numbers (this roughly means that two particles cannot be in the same place with the same velocity). The common idea that "matter takes up space" actually comes from the Pauli exclusion principle.

The quarks and the leptons (including electrons and neutrinos), which make up what is classically known as matter, are all fermions with spin 1/2. The quarks take place in the strong and electroweak interactions. However leptons only do in the electroweak.

Elementary fermions with other spins (3/2, 5/2 etc.) were not observed yet, as of 2014.

The elementary particles which are carrying forces are all bosons with spin 1. They include the photon which carries the electromagnetic force, the gluon (strong force), and the W and Z bosons (weak force)

The third type of particle is the Higgs boson with spin 0. The SM has theoretically predicted one Higgs boson [4], however some other theories claim that there are more. In 2012 two experiments of the Large Hadron Collider (LHC) found a Higgs boson like particle. [5,6,7] Existence of the SM Higgs boson was proven in 2012-2013 by both the ATLAS and CMS experiments at CERN. [8]

The Higgs mechanism causes the mass to most of the elementary particle by interacting with them.

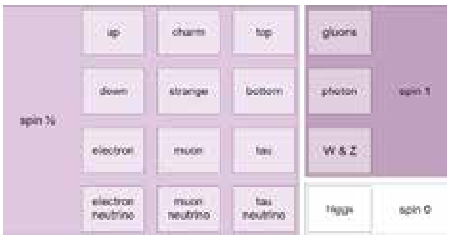

Figure 1: Classification by spin: The spin-1/2 particles are fermions, those with integer spins are bosons

Classification according to the role in the interactions

The other type of classification is according to the role in the interactions, and how they are related to the known four interactions. These are Gravitation, Electromagnetism, Weak interaction, and Strong interaction. Gravitation effects everything, but its role is important at the universal scale. Weak interaction effects everything as well, and electromagnetism effects every electrically charged particle or interacts with uncharged magnetic force fields. Strong interaction produces effects only in extremely small scale.

Particles which interact by the strong interaction, like baryons, are called hadrons. Baryons are both hadrons and fermions (such as protons and neutrons, made of three quarks), and mesons are those, which are bosons as well (such as pions, made of one quark and one antiquark).

Particles that do not interact by the strong interaction are called leptons.

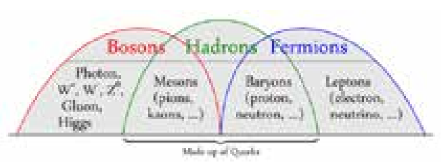

Figure 2: Classification of the Standard Model particles

Symmetries

The Standard Model is based on quantum field theories in which the certain degrees of freedom of the physical space can be chosen independently at various points in the geometric space. These kind of theories are called gauge theories and the symmetry, which comes from the freely chosen degrees of freedom, is called gauge symmetry.

The fundamental symmetry of SM is the Strong interaction which is the consequence of SU(3) gauge symmetry. Symmetry means that we can freely choose the degrees of freedom of the three quarks. The degrees of freedom are called colours for the sake of simplicity.

$$G = SU(3) \times [SU(2) \times U(1)]$$

The symmetry merges the electromagnetic and the weak interactions into the electroweak theory.

$$SU(2) \times U(1)$$

Particle content

Antiparticles

In the Standard Model every fermion has an antiparticle having the same mass and is of opposite charge. For example, the antiparticle of the electron is the positively charged electron, which is called positron. If an electron encounters a positron, they annihilate into two or three gamma rays by converting their mass entirely into energy.

The Big Bang should have created as much matter as antimatter. But today, everything we see from the smallest entities on Earth to the largest stellar objects in the Universe are made almost entirely of matter. One of the greatest challenges in physics is to figure out what happened to the antimatter, or why we see matter/antimatter asymmetry.

Quark Model and fermion families

The quark model originally was intended to organize the huge number of hadrons that were being discovered starting in the 1950s and continuing through the 1960s.

Quark model consists of six particles, which are related in pairs, or generations. The lightest and the most stable particles make up the first generation, whereas the heavier and less stable particles belong to the second and third generations. All stable matter in the universe is made from particles that belong to the first generation; any heavier particles quickly decay to the next most stable level. The six quarks are paired in the three generations – the "up quark" and the "down quark" form the first generation, followed by the "charm quark" and "strange quark", then the "top quark" and "bottom (or beauty) quark". Quarks also come in three different "colours" and only mix in such ways as to form colourless objects. (Figure 3.)

The quark model in its modern form was developed by Murray Gell-Mann and Kazuhiko Nishijima. Gell-Mann received the Nobel prize for his work in 1969 [9].

The next step from Quark Model towards the SM was the GIM–mechanism, which was named after Glashow, Iliopoulos, and Maiani. The fermions were organized in three fermion families by them. The six leptons are similarly arranged in three generations like the quarks: the "electron" and the "electron neutrino", the "muon" and the "muon neutrino", and the "tau" and the "tau neutrino". The electron, the muon and the tau all have an electric charge and a sizeable mass, whereas the neutrinos are electrically neutral and have very little mass.

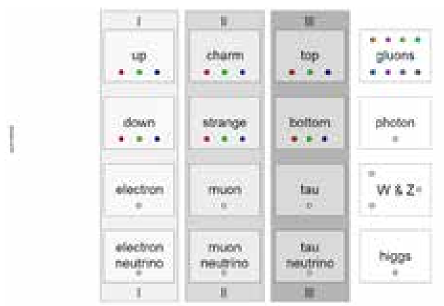

Figure 3: Fermion generations: ordinary(I), exotic(II) and very exotic(III)

Interactions

According to the SM the interactions came from the local symmetries and they are carried by bosons. These bosons not only exist as carriers, but as free, elementary particles as well. They can be observed experimentally too [12].

Electroweak interaction

The particle that carries the electromagnetic interaction is called photon. Particles interact weakly through the exchange of W or Z bosons — the carriers of the weak force. For example, when a neutron decays into a proton, a W boson is responsible. When a neutron captures a neutrino, a W boson mediated.

Strong interaction

The model used to describe the interaction of coloured particles through the exchange of gluons is known as quantum chromodynamics (QCD). The force between quarks is called the colour force.

While quarks have colour, the particles that they make up are colourless. The red, blue, and green quarks present in every particle come together to make a colourless particle. A meson is composed of a colour quark and an anti-colour anti-quark, thus cancelling the colours out.

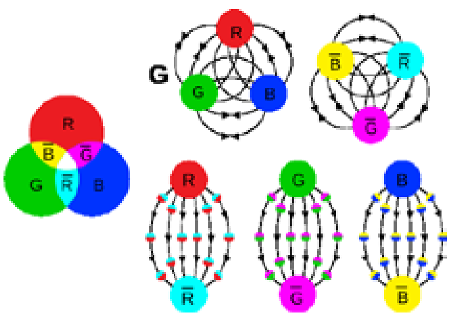

Figure 4: The colourless combination using the colour charges (G is the gluon field)

It is called the strong interaction since it results in forces in the nucleus that are stronger than the electromagnetic force. Without the strong force, every nucleus would blow itself to smithereens.

Imperfections of the Standard Model

Phenomena not explained

The Standard Model is inherently an incomplete theory. There are fundamental physical phenomena in nature that the Standard Model does not perfectly explain:

Gravity

One of the most important phenomena that the Standard Model does not explain is gravity. One approach to solve this problem is to simply add a new particle "graviton" to the Standard Model. However this solution does not recreate what is observed experimentally.

Moreover, the Standard Model is widely considered to be incompatible with general relativity, which is the most successful theory of gravity to date.

Dark matter and dark energy

Cosmological observations quantified the SM explains about 4% of the energy present in the universe.

About 27% that is considered to be dark matter, would behave just like other matter, but it only interacts weakly with the standard model fields. Yet, the Standard Model does not supply any fundamental particles that are good dark matter candidates [13].

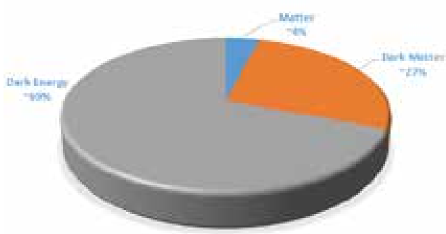

Figure 5: Composition of the Universe

The rest should be dark energy, a constant energy density of the vacuum. Attempts to explain dark energy in terms of vacuum energy of the Standard Model lead to a mismatch of 120 orders of magnitude.

Neutrino masses

According to the Standard Model, neutrinos are massless particles. However, neutrino oscillation experiments have shown that neutrinos do have mass. Mass terms for the neutrinos can be added to the Standard Model by hand, but these lead to new theoretical problems. For example, the mass terms need to be extraordinarily small and it is not clear if the neutrino masses would arise in the same way that the masses of other fundamental particles do in the Standard Model.

Matter/antimatter asymmetry

The universe is made mostly out of matter. However, the Standard Model predicts that matter and anti-matter should have been created in (almost) equal amounts if the initial conditions of the universe did not involve disproportionate matter relative to antimatter. Yet, no mechanism sufficient to explain this asymmetry exists in the Standard Model.

Experimental results not explained

No experimental result is widely accepted as contradicting the Standard Model at a level that definitively contradicts it at the "five sigma" (i.e. five standard deviations). This level is widely considered to be the threshold of a "discovery" in particle physics.

Every experiment contains some degree of statistical and systematic uncertainty, and the theoretical predictions themselves are also almost never calculated exactly.

In either case, the physicists' goal is to determine if a result is a mere statistical or experimental error. But on the one hand, it could be the sign of new physics.

One of the most notable examples is the following:

Muonic Hydrogen in the Standard Model makes precise theoretical predictions regarding the atomic radius size of ordinary hydrogen (a proton-electron system) and muonic hydrogen (a proton-muon system in which a muon is a "heavy" variant of an electron). But the measured atomic radius of muonic hydrogen differs significantly from the predicted radius using existing physical constant measurements by what appears to be as many as seven standard deviations. [11]

Conclusions

The accuracy of the Standard Model is proved by several experimental observations. One of most important achievements of the SM is that it could predict the mass of the W and Z bosons. For the experimental results C. Rubbia and S. van der Meer were awarded with the Nobel prize in 1984. [13] The Standard Model was created more than 30 years ago and since then all of its predictions were completely right. With the discovery of the Higgs boson the SM was roughly completed. As a result of it, P. Higgs and F. Englert were rewarded with the Nobel Prize in 2013 [14]. On Figure 6, we can see a Higgs boson. Although, the SM is not totally perfect, the possibility for a more precise theory is still open, for which the conditions are better than ever.

After all the table which shows all the properties of the Standard Model is shown in Figure 7, where we can see the mass, the charge, the spin and the types of the elementary particles.

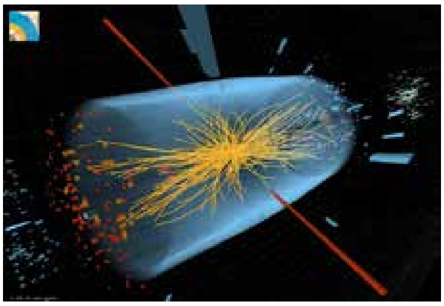

Figure 6: A Higgs event in the Compact Muon Solenoid at the LHC

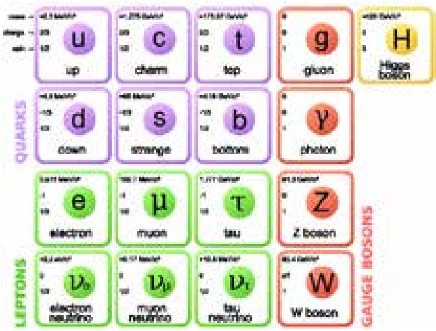

Figure 7: The Standard Model of Particle Physics

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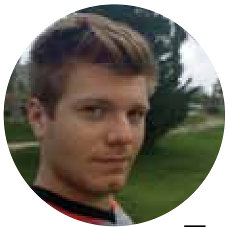

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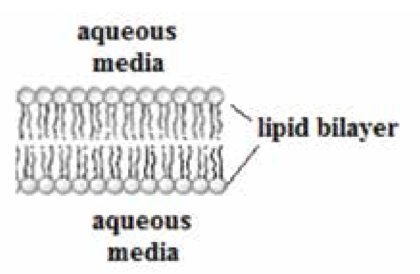
Liposomes: model of cell membranes and drug carrier systems

Liposomes are lipid vesicles made of phospholipids consisting of one or more bilayers surrounding aqueous compartments [New, 1990]. Etymology of the name liposome is derived from two Greek words: lipos = fat and soma = body. Since their discovery by Bangham et al. in 1960s, they were used mainly as models of cell membranes, due to their structural similarity with the biomembranes [Bangham, 1983].

The liposomes could be made by dispersing lipids in an aqueous medium. In the lipid bilayer that results from this process quickly and spontaneously by of a self-assembling process, amphiphilic molecules are oriented so that the hydrophilic heads of lipid molecules to be located at the lipid-water interface (Figure 1) and the hydrocarbon chains to be restricted within the bilayer inside, without contact with water media.



Starting 1970s, these lipid spheres have been used as drug delivery systems. The presence of two different environments in their structure: the aqueous compartment(s) and the hydrophobic inside of the lipid bilayer(s), liposomes could be versatile carriers for a wide variety of hydrophobic, hydrophilic or amphipathic therapeutic agents. Liposomes are widely used in the pharmaceutical industry for the study of drug action, as well as in medicine: gene therapy, in establishing medical diagnoses (fluorescent liposomes), as adjuvant in vaccination [Couvreur & Vauthier, 2006] or as "vehicles" carrying oligonucleotides, antigens, drugs, thus decreasing drug toxicity [Hermanson, 2008]. Incorporating these drugs in liposomes extends their duration of action, reaching the target organ in the concentration required.

The liposomes are also employed in photodynamic therapy for photochemical eradication of malignant tumors [Derycke & Witte, 2004].

For extraction and detection of antibodies in biological samples, it is necessary the liposomes entrapping magnetic nanoparticles (magnetoliposomes) are very useful using [Vo-Dinh, 2003]. Magnetoliposomes are of high importance in drug delivery, as they can be guided and localized to the therapeutic site by external magnetic field gradients and used in cancer treatment by hyperthermia [Dandamudi & Campbell, 2007]. The studies of García-Jimeno et al. (2012) confirmed that it is possible to target drugs encapsulated in magnetoliposomes by means of an external magnet; this method can be used to treat the inflammatory process or other pathologies, and it can reduce the drug concentration administered and increase the efficacy of the treatment.

A number of arguments justify the use of liposomes as "carriers" of drugs [Swarbrick & Boylan, 1994]: liposomes are biocompatible due to their biodegradability and low toxicity, and can serve as a "device" for the controlled release of the drug in body fluids and in the cells. The liposomes may be administered in several ways: ocularly, pulmonary, nasally, orally, intramuscularly, subcutaneously, topically or intravenously.

Another interesting application is the use of liposomes as "bioreactors" [Nardin et al., 2001; Noireaux & Libchaber, 2004]. Liposomes are a model for many fundamental studies [Phillipot & Schuber, 1995; Lasic, 1995] in the following fields:

- Mathematics (topology of two-dimensional surfaces in three-dimensional space, governed only by bilayer elasticity);

- Physics (aggregation, fractal, soft and hard materials);
- Biophysics (permeability, phase transitions, photophysical studies);
- Physical chemistry (colloid behavior in a system with well-defined physical forces, inter- and intra-aggregate DLVO theory);
- Chemistry (photochemistry, photosynthesis, artificial catalysis, micro-compartmentalization);
- Biochemistry (reconstitution of membrane proteins into artificial membranes);
- Biology (models of biological membranes, cell functioning study using liposomes as a tool for restoring biological membranes, the elucidation of the mechanisms of membrane fusion, cell recognition, immunological studies).

In cosmetics, liposomes are used as a platform delivering different ingredients or drugs, and also as penetration enhancers of different active substances into the skin; they can be included in creams, gels or lotions [Lasic, 1995; Paye et al. 2006]. Vyas et al. (2013) reported a novel liposomal gel formulation of caffeine that could reduce the cellulite depositions over human body.

Recently, liposomes bearing a natural porphyrin: chlorophyll a, were used as building blocks to design antioxidant and antimicrobial materials [Barbinta-Patrascu et al., 2014].

The liposomal composition can be infinitely modified and thus creating smart materials with multiple applications.

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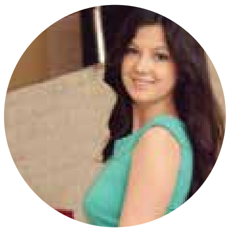
BY MARCELA ELISABETA BARBINTA PATRASCU & ANCA BONCIU



Anca Florina Bonciu is a student of Faculty of Physics, University of Bucharest, Romania. She is set to graduate in 2016 Medical Physics and hopes to also start working in scientific research. In addition, she is an active member of the Association of Physics Students of the University. She recently collaborated on different articles with her teacher, Dr. Marcela Elisabeta Barbinta-Patrascu, and she is enthusiastic about the opportunities that a scientific researcher career can offer to you.

Raman Spectroscopy: Cancer Diagnosis in a Flash

When Sir Venkata Raman discovered the effect which was to be named after him in 1928(1), he had visions of shedding light on problems relating to radiation, optics and thermodynamics(2). Little did he know that less than a century later his discovery could be used as an innovative method to detect the disease which will affect one in three of the population – cancer.

The Raman Effect

When a photon is incident on a molecule there are three scenarios which can occur (shown in Figure 1). The case where there is no net energy transfer within the molecule is known as Rayleigh radiation, which was observed by Lord Rayleigh in the late 19th Century(4,5,6,7). In this instance, frequency of the incident photon is equal to that of the emitted photon, which is by far the most common scenario.

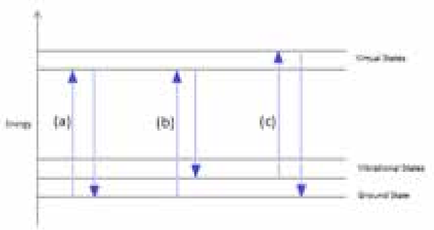


Figure 1: An incident photon absorbed by a molecule can undergo either Rayleigh (a), Stokes (b) or Anti-Stokes (c) radiation.

The effects which were observed by Raman are far less common. If the incident photon is of a higher frequency than the emitted photon (i.e. the photon has lost energy to the molecule) this is known as Stokes radiation. Only around 1 in 107 photons illustrate this effect. Anti-Stokes radiation occurs when the molecule is already in an excited state before absorbing the incoming photon. The incoming photon absorbs the energy from the molecule, resulting in the emitted photon being of higher frequency than that of the incident. From the Boltzmann Distribution, fewer molecules begin in an excited state therefore Anti-Stokes radiation is observed even less frequently than Stokes. It is for this reason that Raman Spectroscopy concerns itself only with Stokes radiation.

What is Raman Spectroscopy?

Raman Spectroscopy is a form of emission spectroscopy – an excited molecule falls from a high energy state E_2 to a lower energy state E_1, emitting a photon in the process. A Raman spectrum shows a plot of scattered intensity as a function of the difference in energy between the incident photons and the scattered photons. When only considering the Raman case (i.e. Stokes and Anti-Stokes scattering) the spectrometer shows that the difference in frequency solely corresponds to the vibrational modes of the material being analysed. Every substance has a different Raman spectrum, making one compound differentiable from another.

Cancer Detection

Fluorescence spectroscopy was one of the first optical spectroscopic techniques to be used for the detection of cancer. Although it has proved successful in distinguishing between normal and abnormal tissue, there is a lack of ability to differentiate between these abnormalities. Since the early 1990s, Raman Spectroscopy has become of increasing interest to those researching medical diagnostics as a solution to this problem. Many biological molecules are Raman active - each having their own unique fingerprint. The subtle differences indicating cancer include an increased nucleus-to-cytoplasm ratio, changes in lipid and protein levels, a high metabolic activity and disordered chromatin. Raman spectroscopy has the capability to detect each of these subtleties independently. For this reason, Raman is being seen as the modern approach to the detection of cancers and pre-cancers.

Detection by Raman spectroscopy of cancer of the skin, breast, colon and cervix have already been illustrated, however the in vivo applications of this technique are by no means limited to cancer diagnosis. Raman spectroscopy has also been proven to diagnose other diseases such asatherosclerosis and vulnerable plaque.

Instrumentation

The most commonly found setup for creating a Raman spectrum of a tissue sample is shown in Figure 2. A non-ionising laser illuminates the sample via a fibre-optic probe. This probe then filters out both the transmitted laser light and the Rayleigh scattered light, transferring only the information regarding the Raman scattering to the spectrograph. This is the preferred method when performing experiments in vivo: its non-invasive manner is particularly appealing to both researchers and (in future) patients alike. It also allows the diagnostic testing to be done in real time and with no biopsy necessary.

When using Raman spectroscopy in vivo there are several filters found within the probe. The first of these is the band-pass filter which is required to prohibit the illumination of the sample by the Raman scattered photons. The long-pass filter prevents both the Rayleigh scattering and the non-absorbed laser light from creating additional Raman scattering. Since the optical fibres are fused silica-based, they will produce their own Raman scattering. A third filter must therefore be used in order to minimize the signal produced by them.

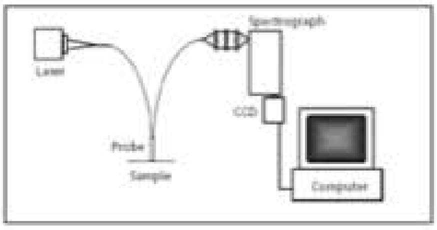


Figure 2: A typical diagram of apparatus for creating Raman spectra in vivo (Adapted from "Raman Spectroscopy for Cancer Diagnosis")

The Signal-to-Noise Ratio

The higher the signal-to-noise ratio, the more reliable the results will be. In order to reduce the significance of the noise, the length of time over which the data is acquired (integration time) should be maximised. When considering clinical applications however, the practicalities of this must be considered. Any movement of the probe will increase the error in measurement. The longer the integration time, the more likely it is that the probe will be moved – inducing further error.

An Example – Cervical Cancer

Cervical cancer is the third most common cancer found in women. Of these cases, the human papilloma virus (HPV) is found in 99.7%. Early detection of this virus is therefore crucial to the diagnosis of HPV-associated neoplasia.

The current method for detecting the virus is the Papanicolaou (Pap) smear. This involves the exfoliation of cells from the cervix and for them to then be examined under a microscope for abnormalities. Although this method is effective, a significant number of false positives/negatives have been recorded. This process is also rather labour-intensive; probing researchers to look for a new, innovative method to detect HPV.

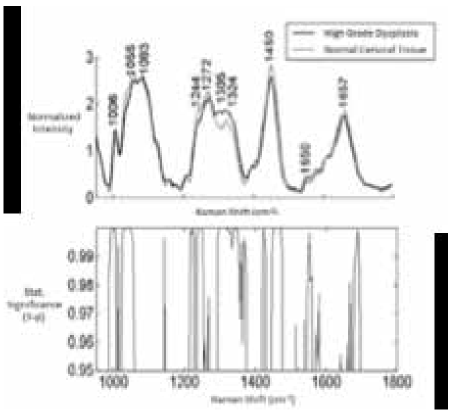


Figure 3: Overlay of High Grade Dysplasia Raman spectrum on normal cervical tissue Raman spectrum (Top) and results of a t-test performed at each wave-number (Bottom). Adapted from Robichaux-Viehoeveretal.

In 1998, Mahadevan-Jansen et al. developed the first fibre-optic probe to be used to detect cervical cancer in vivo. Four years later, Robichaux-Viehoever completed her PhD thesis under Mahadevan-Jansen, conducting the largest in vivo study using Raman spectroscopy for the detection of cancer up to that point in time. Her study entitled "Characterization of Raman Spectra Measured InVivo for the Detection of Cervical Dysplasia" analysed data from 66 patients (33 normal and 33 dysplasia) using the statistical method known as logistic regression. It was found that the difference in Raman spectra between high-grade dysplasia and normal cervical tissue was small yet distinct. As shown in Figure 3, several spectral regions including 1006, 1055, 1305-1330 and 1450 cm^{-1}show statistical significance at $p<0.001$ and other peaks (i.e. at 1550 and 1655 cm^{-1}) show significance at $p<0.01$. This significance at low p-values suggests that these results are reliable and are not simply the result of pure chance.

A problem encountered by this study was that variance from patient to patient altered the results more than had been hypothesized. Robichaux-Viehoever et al. showed that the woman's menopausal state varied the results significantly and that the spectra would need to be modified accordingly. Kanter et al. took this into account and proposed methods in which both the menopausal state and the stage of the menstrual cycle can be corrected for.

The studies above have all focussed on the difference in intensities within the fingerprint region – the case where the Raman shift is between 800 and 1800 cm-1. This trend is not unique to the works mentioned here – most in vivo Raman spectroscopy data features only the results from this region(,,). In most forms of optical spectroscopy, the fingerprint region is the only area considered when testing organic molecules. Any peaks observed out with this region are generally ignored as they are often the result of noise.

In 2005 however, Santos et al presented a setup for the characterisation of tissue in vivo by the analysis of the high wavenumber region (2400-3800 cm^{-1}). The fused-silica core only produces significant Raman scattering within the fingerprint region therefore the simple setup of a single, unfiltered optical fibre could be used in this case. This study also tested a range of different materials from which the optical fibre could be made, cladded and coated. The combination which gave rise to the least noise was the fused-silica core and cladding, coated with acrylate. When tested ex vivo, this gave positive results leading to the conclusion that the next step would be to repeat the experiment in vivo. Continuing on this theory, Mo etal performed a study which did just that.

Using a specially designed fibre-optic probe based on the one sampled by Santos et al, data from 92 Raman spectra (46 normal and 46 dysplasia) was collected from a total of 46 patients to be analysed in the high wave-number region. The addition of a ball lens allows the light to be coupled both in to and out of the fibre as shown in Figure 4. Using this arrangement, several spectral differences can be seen between the normal and dysplastic tissue (Figure 5). In the region of 2800-3000 cm-1, the intensity of the Raman shift is lower for the dysplasia case whereas for higher wave-numbers (3100 - 3700 cm^{-1}) the intensity is greater. Each of these regions show statistical significance at $p < 0.001$. Multivariate Statistical Analysis was then performed to confirm this result. The study concluded there was enough evidence to be able to differentiate between normal cervical tissue and cervical tissue at different grades of dysplasia.

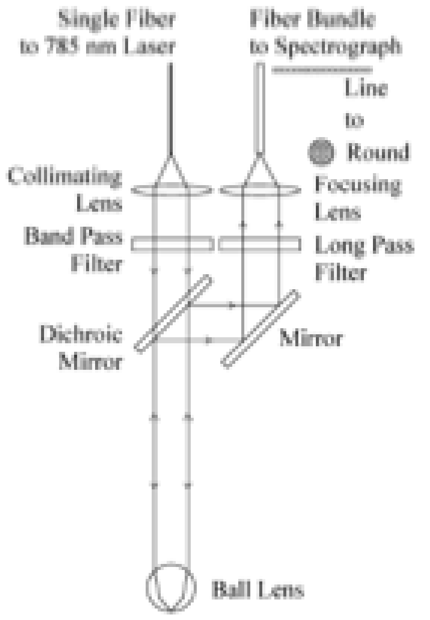


Figure 4: Optical layout of Raman probe. Picture from Mo et al.

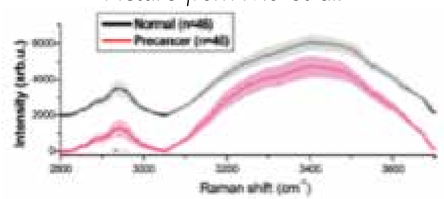


Figure 5: Comparison of mean in vivo high wave-number Raman spectra ± one standard deviation. (Intensity measured in arbitrary units) Picture from Mo etal.

By considering the full spectrum (both the fingerprint region and high wave-number region) even more accurate predictions can be made. The two techniques are complementary and the simultaneous Raman spectroscopy of the two could become a very promising diagnostic tool in future.

Looking Ahead

After authoring several papers on the subject, Dr Fiona Lyng and her colleagues at the Dublin Institute of Technology have recently patented a method for analysing a biological sample by Raman spectroscopy. Having won Enterprise Ireland's "One to Watch" Award in 2011, the team are now planning to commercialise this technology, specifically in the form of a cervical cancer analyser.

Named a "High Sensitivity, High Specificity Cervical Cancer Analyser", this product has a lot to live up to. It is advertised as being low cost, fast and easy to use – not to mention the significant decrease in the risk of human error. This is an in vitro application of Raman spectroscopy – patients will continue to attend their regular Pap smear and the exfoliated cells will be analysed with this new technology. For those studying the diagnostic applications of Raman spectroscopy this is a huge step in the right direction. It is hoped that in the near future, Raman spectra will be a common sight in many cancer diagnostics departments and humankind will be one step closer to winning the battle against cancer.

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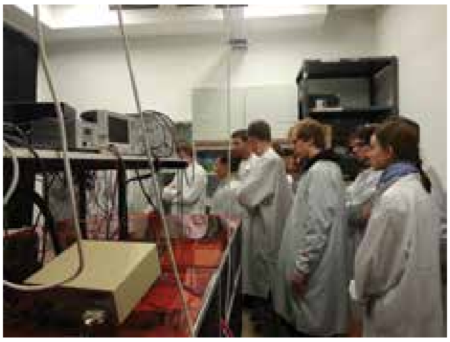
BY DANIELLE HARPER

The Mafihe-jDPG Autumn School

An international autumn school was organized jointly by NC Hungary (Mafihe) and NC Germany (jDPG) between November 21-24, 2013, in Budapest. Twenty physics students from all over Germany travelled to the city to attend lectures about the physics of complex systems, take laboratory tours and, perhaps most importantly, get to know each other as well as Hungarian students.

Most participants met first in the evening of Thursday, November 21, at Adagio Hostel, Budapest. It soon turned out that everyone was really open, friendly and patient, which was in fact necessary to survive the (otherwise painfully long) check-in procedure of the Hostel. After a hearty dinner, however, we visited the Opera Pub in Budapest downtown, where the introduction could continue with the assistance of some wine and pálinka.



The scientific programme started on Friday morning, with a visit to the von Kármán Wind Tunnel Laboratory at the Technical University of Budapest (BME). In this laboratory, the spreading of air pollution can be modelled for extended urban areas, for example, but the aerodynamic investigation of a large variety of objects (e.g. vehicle models) is also possible here. An enthusiastic PhD student talked about the research taking place in the laboratory and showed us some of the spectacular experiments in operation, too. After lunch, we went on to the neighbouring campus of Eötvös Loránd University (ELTE) to attend five guest lectures given by prominent physicists. The main focus of the school was the physics of complex systems, therefore we invited professors István Csabai (talking about data deluge in physics), Gergely Palla (complex networks), Imre Jánosi (laboratory modelling of large-scale environmental flows), Jenő Kürti (carbon nanostructures) and Tamás Vicsek (flocking and collective motion). In the evening, we returned to the hostel to discuss the operation, benefits and opportunities of IAPS, jDPG and Mafihe. At the end of this long day, we wandered once more into the old town to catch another glimpse on Budapest by night as well as to relax a little.

Early the next morning, the group departed by train to Szeged, the third largest town in Hungary, where members of the Mafihe local committee were already waiting for us. We then visited two advanced femtosecond laser laboratories at the University of Szeged (SZTE), whose research pave the way for the future Extreme Light Infrastructure, to be built on the outskirts of the town within the next few years. The ultra-short, ultra-high intensity light pulses are of great interest for various reasons. The interaction of light and matter can be studied with great accuracy, but they also contribute to the foundation of new technologies like tabletop particle accelerators and relativistic microelectronics.

Having finished with the lasers, we climbed to the tower of the Szeged Cathedral with an excessively entertaining native guide who, besides showing the sights, also had a number of interesting stories about the culture and history of Szeged. We also had some time to get to know our colleagues from the town before having to travel back to Budapest in the evening.

On Sunday morning, a number of participants presented their own fields of research at the ELTE campus, which was followed by the closing of the School and the farewell.

In total, the autumn school was a very enriching experience for all participants and hopefully, it was only the start for a future collaboration between the two associations and also for the improvement of the relations between physics students from different countries.

by Márton Lájer

PLANCKS 2014

Initiative of students of Utrecht University, the Netherlands

From Friday, 23rd till Sunday 25th May, 32 teams of students from 14 countries, participated in PLANCKS, the first international theoretical physics competition. PLANCKS was instigated and organised by students of Utrecht University in the Netherlands. Their opening symposium became great news, when they managed to attract Professor Stephen Hawking to give a lecture. Participants look forward to the next edition.

"We want to say DANK U WEL! We had an amazing weekend here in Utrecht and we were truly impressed by the excellent organisation. The only thing we can blame you for is the fact that half of our group is now seriously considering to delay their graduation in order to be allowed to participate in PLANCKS 2015!" Thus read one entry in the guest book, but there were many more along the same lines.

PLANCKS

The Physics League Across Numerous Countries for Kickass Students, (PLANCKS), was instigated by the students of A-Eskwadraat, the study association of Utrecht University which caters for students of Mathematics, Computer science, Information science, Physics and Astronomy. The association is allied to SPIN, an umbrella organisation for Dutch study associations specifically in the field of physics. In 2012 the new, ambitious SPIN committee proclaimed the ambition to give a facelift to the annual Dutch national physics competition, PION, that existed since 1995. Thus PLANCKS was born.

This first edition attracted no less than 32 teams of between 3 and 4 students, from 14 countries as far away as China. The actual competition took place on the morning after the opening symposium, during which the teams had to make 10 challenging assignments carefully composed by scientists from different institutions. The event was sponsored by Utrecht University, several companies and funding agencies.

Stephen Hawking

Since they wanted good PR for their initiative, the organising committee decided to send an email inviting Professor Hawking for the opening symposium, thinking, 'We've got nothing to lose.' To their surprise, a reply arrived almost by return saying he would be delighted.

When the news of Hawking's coming was made public, it soon became clear that a great number of the general public very much wanted to be present at the symposium. The students decided to rent a Theatre Hall for the symposium which can hold 1500 and extend their organising team of 8 with 4 more students. The tickets for the 500 seats they reserved for the general public were sold out within 1 minute.

Professor Hawking took the stage to a reception the Stones would have been jealous of. Especially for the opening symposium he wrote a new lecture, which included recent work on BICEP (Background Imaging of Cosmic Extragalactic Polarization).

When after his lecture he was asked 'Do you think scientists have an obligation to convey their knowledge to the lay audience and why?', Hawking answered: 'It is important, that we all, have a good understanding of science and technology. Science and technology are changing our world dramatically, and it is important to ensure that these changes are in the right directions. In a democratic society, this means that we all need to have a basic understanding of science, so we can make informed decisions ourselves, rather than leave them to the experts.'

Besides Stephen Hawking, the PLANCKS organisation also managed to attract theoretical physicist and Nobel Prize Winner Professor Gerard 't Hooft of Utrecht University and experimental physicist Professor Immanuel Bloch Director of the Max Planck Institute in Munich, who received the Körber European Science Prize 2013.

Winners

At the award ceremony Professor Gerard 't Hooft presented the prizes. The third prize was shared between Smoluchowski's Team from the Jagiellonian University in Poland and NOFY066 from the Charles University in Prague, Czech Republic. Second prize went to Tena, a home-grown mixed team from

Images courtesy of Ruben Meuwese/A-Eskwadraat

Utrecht, Nijmegen and Eindhoven Universities, and the winners were another mixed home-grown team, Dutch Physics Olympiad from Utrecht and Nijmegen Universities. The winning students, Troy Figiel, Ruben Doornenbal, Martijn van Kuppenvelt en Joost Houben, had not expected to achieve such a high score. Even so, they were the best by a considerable margin. First prize was a cheque for € 2109,14; (h/pi.10^{37}; h is the Planck Constant), together with a trophy in the form of a plank.

At the end of the awards, the baton was passed to Irene Haasnoot of Leiden University which will organise PLANCKS 2015. From 2016 on, the Dutch initiators hope PLANCKS will start touring around the world.

By John Donnelly

PLANCKS Challenge: Newton's Cradle

Jan van Ruitenbeek, Leiden University

Newton's cradle is a well-known gadget and physics demonstration. It is usually described as demonstrating the laws of conservation of energy and conservation of momentum.
For simplicity we take the motion to be one-dimensional and the collisions to be elastic.

[1] *5 points* We launch a single ball onto the other balls that are at rest, and consider the situation just after the collision. For any number N of balls (including the launched ball) in the cradle how many solutions do the laws of conservation of energy and momentum permit? For $N = 2$ and $N = 3$ describe the set of allowed solutions in N-dimensional velocity space.

[2] *5 points* When we perform the experiment for $N = 3$ we find that only one solution is realised. Which solution is this, and explain why.

image by: Max Schlösinger