Particles

The Physics Work Experience Newsletter

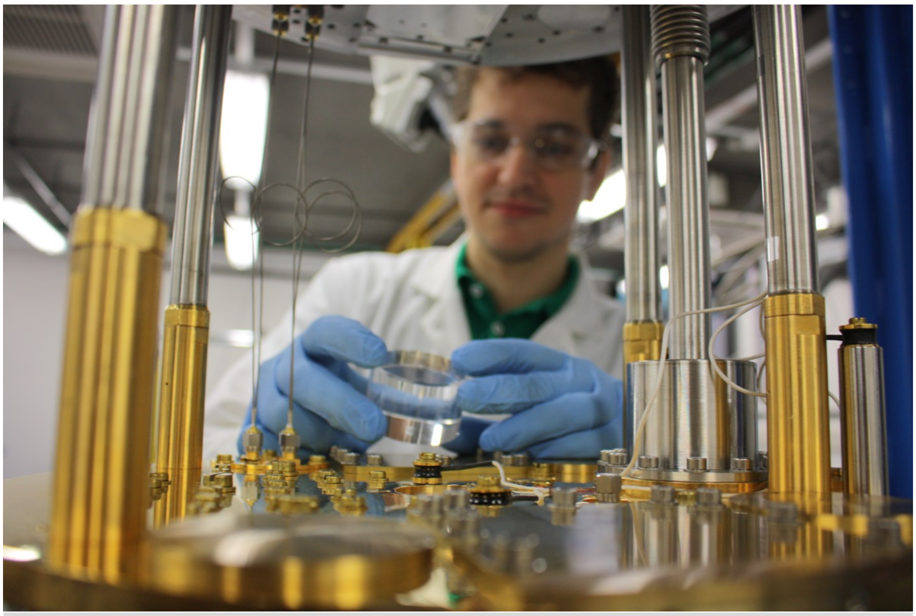
Issue 8 | September 2016 |

THE UNIVERSITY OF WESTERN AUSTRALIA

SEEK WISDOM

Particles is a 'mini-newsletter' which is produced as part of the School of Physics Science Journalism Work Experience Programme. This edition was created as part of the work experience by Year 10 students: Liam Ryan, St Stephen's Duncraig and Massimo Mckie, St George's Anglican Grammar School, Perth.

Hell Might Just Freeze Over



Pic 1: Maxim holding one of the sapphires along side the BlueFors dilution refrigerator

Ivanovo. One of the coldest places on earth, just east of Moscow. Whilst it may get extremely cold there, down to –30ºC most years and –40ºC when the gods aren't playing nice, a young globe trotting scientist has managed to bring that environment here, to sunny Western Australia. Well, perhaps a tad colder, something in the region of 20 millikelvin (mK; -273.148ºC) in fact. This is one of the coldest environments ever created. So lets see how this has been achieved right at our very doorstep.

Cryogenics is the study of the extremely cold, and by that we mean *really* cold. For the modern world's developing technology, it is crucial that we take part in this developing area of physics. And the way UWA is helping in this effort, is with the BlueFors dilution refrigerator which is UWA's coolest piece of equipment, both literally and figuratively, opening up a whole realm of opportunities in the field of quantum mechanics and cryogenics at temperatures close to absolute zero.

From his humble beginnings in Ivanovo, Dr. Maxim Goryachev has now grown to be one of UWA's leading young researchers in the School of Physics. Maxim is also in pole position, working with the two $400,000 dilution refrigerators at UWA. Considering the fact that he is only 30 years old, there is definitely a bright future ahead of him. We were lucky enough to delve into his works and meet him in person, finding out that he was indeed a pretty chilled guy.

Maxim's research is part of the Australian Research Council (ARC)'s Centre of Excellence for Engineered Quantum Systems, also known as EQuS. This Centre of Excellence is made up of several research groups in the University of Western Australia, University of Sydney, University of New South Wales, University of Queensland and Macquarie University.

Opening on the 1st of January, 2011, EQuS has been at the forefront of scientific research into quantum technology and has been a strong part in Australia's revolutionary steps forward in scientific research. Due to its success, it was on the 8th of September 2016, awarded a further $31.9 million over the next 7 years in the latest round of grants from the ARC.

Maxim was brought to Perth because of Professor Mike Tobar's collaboration with various research groups around the world. Mike is a Fellow of the Australian Academy of Science and winner of multiple state, national and international awards, including the 2010 WA Scientist of the Year and the 2012 Alan Walsh medal. Mike is now the EQuS node director who supervises him and gives general direction to all research within the UWA node whilst Maxim creates the experiments, analyses data and writes up research papers, in other words, the "every day stuff".

After Maxim's upbringing in Ivanovo, he moved to France obtaining a Ph.D in engineering at *Université de Franche-Comté* working on cryogenic resonators and oscillators. Ever since he was a young boy he had a passion for science, especially physics, stating

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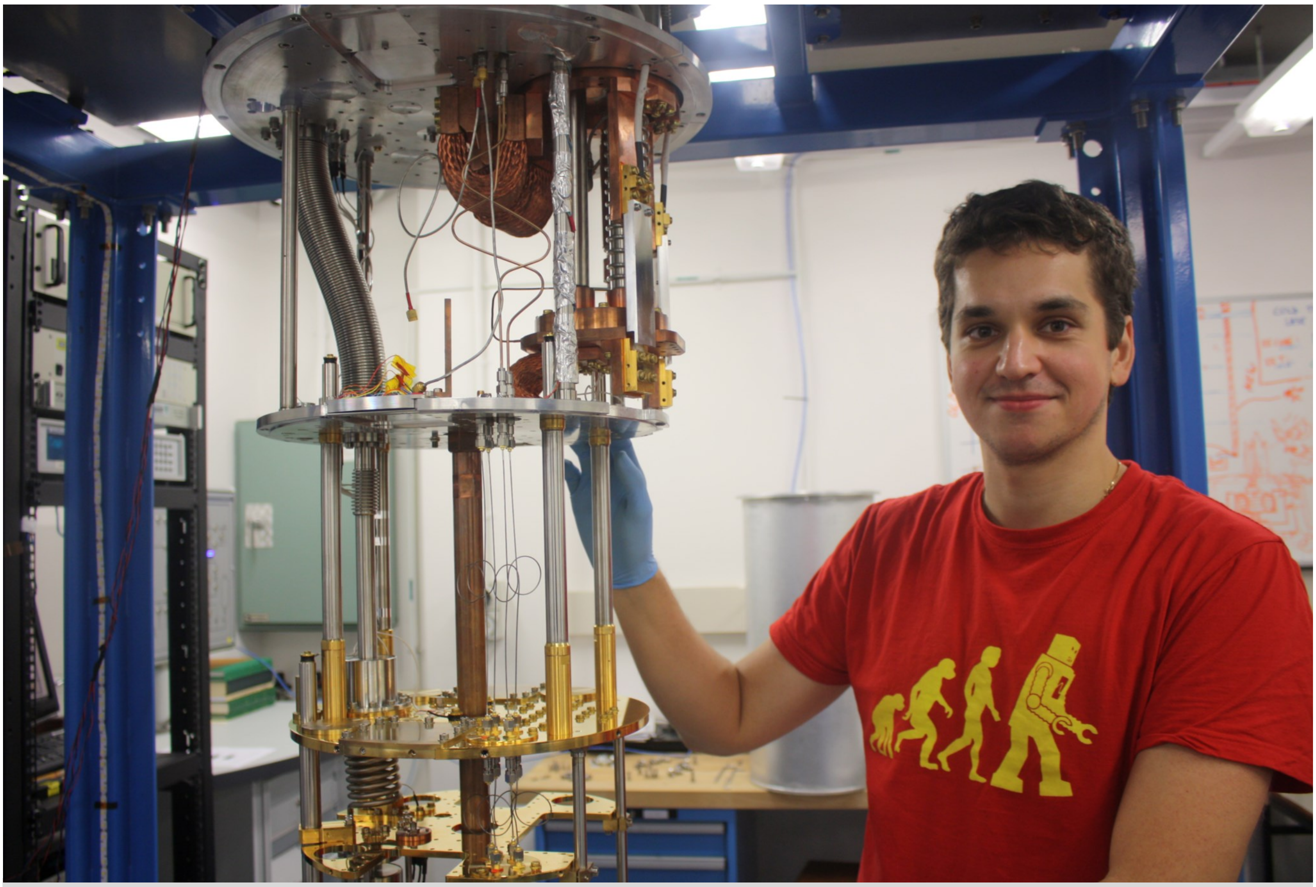


Pic 2: Maxim with his prized possession

that his main inspiration for being a part of this field is "curiosity", and if you're dealing with quantum mechanics, there sure is a lot to be curious about.

Maxim explained that there are 3 main sides to physics. One which is completely theoretical, dealing with theories and pure mathematics whilst there is also experimental physics, testing our current understanding of the Universe. The last side being applied physics which is determined to bring fundamental 'blue-sky' knowledge to real world applications (closely related to engineering).

Early in his career, Maxim was dealing with the more applied side of experimental physics aligned with engineering. In 2012, he decided to move countries again, this time to Australia and began working on more purely experimental physics. Now he says, he "tests the boundaries of the laws of physics", specifically when dealing with extremely low temperatures. One of his tests is known as the Lorentz Invariance test, where Maxim and 'Team Tobar' are testing whether or not the masses of fundamental particles are the same in all directions

He has created many experiments, utilising the BlueFors dilution refrigerator and other quantum engineering systems here at UWA. Some of Maxim's most important research areas are cryogenic bulk acoustic wave devices, low temperature physics, spins in solids and microwave cavities for quantum electrodynamics (QED), with many of his research papers being cited across the world. Some of his most cited works have been in the area of spins in solids and their applications to quantum communication. One of the most influential out of the 29 or so research papers he has published is titled *High-Cooperativity Cavity QED with Magnons at Microwave Frequencies* which appeared in Physical Review Applied in 2014.

Maxim's research is at the cutting edge of scientific development. So much so that his devices include one of the highest quality factor mechanical resonators. This refers to how long a vibration holds relative to its frequency. At UWA he works with ultra-high purity

"We probe the unknown parts of the universe and that is what I love doing."

crystals like sapphire, diamond and quartz which he uses within his dilution refrigerator. These crystals cost in excess of $100,000. They are used to test a whole array of things, as their properties stay very exact at low temperatures. They are also used in cryogenic microwave clocks to keep extremely precise time.

The dilution refrigerators work by having a mixture of Helium 3 and 4 being pumped into the system which then cools down the central chamber to between 6 and 20 mK (1 mK = one thousandth of a kelvin). Testing substances at this temperature raises interesting predicaments. He explained that at this temperature, things like "thermal noise" go down a lot. Part of this is that substances are much less likely to fluctuate in temperature and energy levels, allowing for more precise measurements, thus opening the realm of the quantum world

Being a part of EQuS means that he is part of a huge collective of people striving to create technologies for the future. It also means that Maxim has had opportunities to travel and collaborate with experts in his field with annual conferences held all across globe. Some of the favourite places he has visited on his travels include The University of California at Berkeley and the Laser Interferometer Gravitational -Wave Observatory (LIGO) in Louisiana.

Maxim's dilution refrigerator is used to test out technologies that might be used for future quantum computers and networks and offers new solutions to problems when building and hypothesizing quantum machines.

Currently, he is delving into the possibility of converting information from microwaves into an optical signal to allow two separated quantum computers to communicate. It is these dilution refrigerators and the low temperatures they reach that allow him to test this.

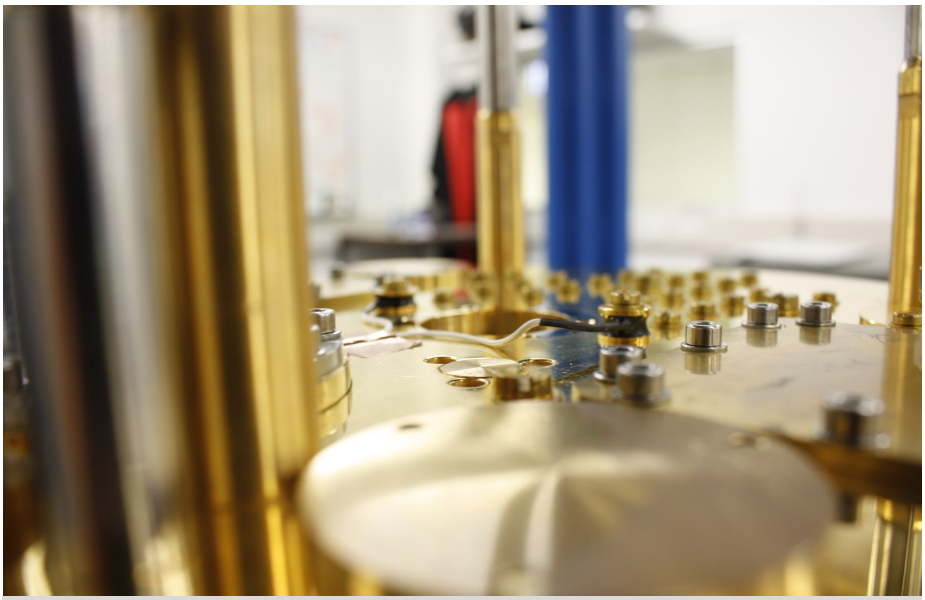
Quantum computers are computers that do not compute by using standard binary bits, but by using Qubits. In a normal computer system, one bit can either be on, or off. Two states, hence Binary, but with qubits, it is both on and off at the same time. This allows for incredibly fast processing power. This means that a normal 64 bit computer would have a memory of 64^2 bytes or ~4GB. But the same computer with qubits would have 2^{64} bytes, or about $1.8x\ 10^{19}$ bytes or about 1.8×10^{14} GB. Needless to say, this is a lot of power. But it goes beyond that. A normal computer must take steps in order to calculate a problem because its bits can only be in one state. A qubit however can be in both states at the same time and therefore, the same problem that may take many steps on a normal computer can be done instantaneously on a quantum one.

Although these experiments are in development right now, and can revolutionise physics, Maxim's long term goal is to help test the "*Universal Equation*", an idea popularized by Einstein himself. The *Universal Equation* or *Unified Theory* would encompass all the laws of physics into one neat theory, combining both Quantum Mechanics (the study of things really really small) and the study of General Relativity (the study of normal sized stuff up to super massive black holes and beyond). This idea has engrossed physicists for decades and has been the main focal point for many of them. To that end, Maxim is providing assistance to a team of researchers who are attempting to discover *axions,* hypothetical particles that are believed to be the elusive dark matter that encompasses our universe.

Dark matter is offered as an explanation as to why many astronomical bodies weigh much more than they should. Our universe is big, really *really* big. It has trillions upon trillions of stars and galaxies and planets but there's a problem. When we observe the visible amount of matter present, it doesn't equate to the actual amount of mass in space. We know this because there are parts in space, which interact with gravity and other astronomical bodies but are completely invisible to the electromagnetic spectrum (hence dark matter). We can see dark matters effects on the universe, but not dark matter itself. This is a problem because this supposed dark matter accounts for around 27% of all the mass in the universe. Hence, making predictions about the universe can be pretty hard when we don't know what 27% of it actually is (although, coupled with dark energy which is directly tied to dark matter, they account for about 84.5% of the unknown, but that's a story for another day).

With Maxim's help, this team of researchers are hoping to solve this mystery, by trying to detect axions. Axions are theorized to be dark matter and if detected will constitute a major breakthrough in physics. They are trying to discover them in the cryogenic fridges by creating an electromagnetic wave in a vacuum cooled down to 20mK. It is hypothesized that when these particles react with an electromagnetic field, they release a photon which we can detect.

It seems that our young researcher's work has the potential to change our world forever. Maxim is testing the limits of our current understanding of physics utilizing some of the most advanced technology in the world. Hopefully we will see Maxim carry on with his incredible research in the future, that is, if he hasn't been accidentally swallowed up into a whole other dimension by mysterious dark energy.



Pic 3: A close look at an engineering marvel

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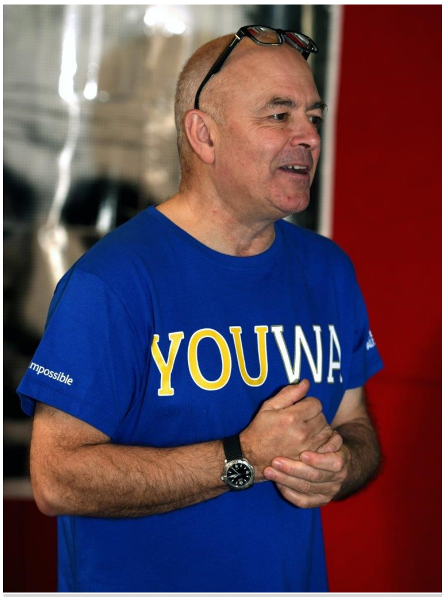
Heads Up!



Professor Ian McArthur
Head of School

This will be my last Heads Up, as after 17 years as Head of the School of Physics, I will be stepping down next year. This coincides with a major restructure of the University, which will see a reduction of the number of Faculties from nine to four - the Faculty of Science, the Faculty of Engineering and Mathematical Sciences, the Faculty of Medicine and Dentistry, and the Faculty of Arts, Business, Law and Education. For reasons that I will not go into here, the School of Physics has chosen to move to the Faculty of Engineering and Mathematical Sciences (which may be renamed the Faculty of Engineering and Mathematical and Physical Sciences, or something similar, down the track). This has not been an easy decision for the School to take.

The University is also moving to a professional staff structure that may leave the School of Physics without a School Manager. We have been incredibly fortunate to have Jay Jay in that role for 9 years now, and it has been his energy and enthusiasm that has driven many outreach activities by the School, including the production of this Alumni Newsletter.

Though we are moving into uncharted waters, the School of Physics will strive to continue the research excellence that has been its hallmark, as well as providing an excellent undergraduate programme for the very talented students it is fortunate to be able to attract. As long as the School continues to focus on this core business, I am sure it will have a bright future.

I would like to thank all the staff in the School for the wonderful support they have provided to me as Head of School. It has been an absolute pleasure to be able to serve the School.

I will still be Head of School for the upcoming Physics Alumni event at 6pm on Friday the 21st of October 2016, and I look forward to catching up with many former staff and students.

Ian McArthur

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