Extreme lab at European X-ray laser XFEL is a go

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"Helmholtz International Beamline" will be build at European XFEL in Hamburg, Germany. Credit: DESY

The Helmholtz Senate has given the green light for the Association's involvement in the Helmholtz International Beamline (HIB), a new kind

of experimentation station at the X-ray laser European XFEL in Hamburg, Germany. As the leading institutes of the international HIB user consortium, the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) and DESY were able to secure funding in the amount of 30 million Euros for this project. The majority of the funding will go to HIBEF - "Helmholtz International Beamline for Extreme Fields", which will be a key addition to the High-Energy Density Science Instrument (HED) at European XFEL.

The goal is that, starting in 2018, the HIBEF infrastructures at HED will be used to conduct experiments under extreme conditions of high pressures, temperatures, or electromagnetic fields. The insights gleaned from these experiments will help improve models of planetary birth, among other things, and will also provide a basis for innovations in materials research and accelerator technologies. "There is a great deal of interest in the joint extreme lab on the part of the international community," says HZDR Scientific Director Prof. Roland Sauerbrey. "Some 100 institutes have already signaled their interest in our research facility." The HZDR will be contributing a facility for materials research using high magnetic fields and a high power laser for ultrashort light pulses capable of heating electrons at the material surface to a temperature of several billion degrees Celsius. In the process, a special state of matter - a plasma, consisting of electrons and ions - is produced.

At the high-power laser DiPOLE, a contribution to the HIB from Oxford University and the British science organization Science and Technology Facilities Council (STFC), matter is subjected to states of extreme pressure and temperatures on the order of several 1,000 degrees Celsius. The states produced within the sample are similar to those found at the cores of planets. An additional goal is that inside special diamond-anvil cells made by DESY, extremely high pressures of up to ten million bars and temperatures in the range of 1,500 to almost 10,000 degrees Celsius can be achieved. "We're charting new scientific territory by paving the

way for the types of experiments that up to now could not be performed," says Prof. Helmut Dosch, chairman of the DESY Board, one of the consortium partners and a chief partner of the European XFEL.

However, extreme conditions can only ever be produced for a few fractions of a second - which is why the extremely short and high-intensity X-ray laser flashes of the European XFEL lend themselves nicely to their analysis. "The new station allows us to replicate extreme conditions existing in outer space right here on Earth and examine them using X-ray laser light," explains Prof. Massimo Altarelli, chairman of the European XFEL Management Board. "We are very pleased that potential users are highly committed to helping us build a top-notch European research facility."

Unique combination for various scientific disciplines

Prof. Thomas Cowan, head of the international user consortium and an HZDR institute director, is convinced that "these experiments will prove immensely popular - not only among materials researchers, but also among geoscientists, astro physicists, plasma physicists as well as chemists and biologists." Which explains why not one but a number of institutes are currently working together to make the HIB a reality. The beamline is divided up into three separate instrumentation projects by the Helmholtz Association at the European XFEL, with funding totaling 29.8 million Euros: Helmholtz International Beamline for Extreme Fields (HIBEF), Serial Femtosecond X-Ray Crystallography (SFX), and Heisenberg Resonant Inelastic X-Ray Scattering (hRIXS).

The unique set of offerings at the HIBEF Beamline will allow for new kinds of magnetism experiments. Using pulsed magnetic fields of 60 tesla - 20 times more powerful than a magnetic resonance tomograph, like the ones used in medicine - researchers will be able to target and

tweak material properties. The European XFEL's X-ray laser flashes will help to probe the electronic structure of sample materials during magnetic pulses both with atomic precision and as a function of magnetic field strength. Among other things, the understanding of these basics could enable new kinds of applications in electronics.

Another focus of the experiments is on plasma physics. Plasmas are special states of nature that occur in stars as well as during particle acceleration using intense laser radiation. The interplay of light and matter, which is based on plasma processes, has raised many as of yet unanswered questions. Scientists hope to solve at least some of them. The study of matter under extreme conditions also pertains to studies of the physical Vacuum. A Vacuum is not simply an empty space; rather, it's a space where particles and antiparticles are continuously created and destroyed - which is why a Vacuum is capable of interacting with highly powerful electromagnetic fields. The researchers' goal is to focus the HZDR's high-intensity laser onto the European XFEL's X-ray beam. By doing so, they are hoping to learn more about the Vacuum's optical properties. At a performance of 100 terawatts, the HZDR's high-power laser will be capable of producing ten ultrashort pulses per second.

The DiPOLE laser, whose costs are amounting to close to eleven million Euros, is currently under construction at the Central Laser Facility of the STFC. At frequencies of ten pulses per second and a performance of ten gigawatts, the laser will be capable of compressing samples. This will allow for the study of material properties under conditions like those encountered at the cores of planets within and outside of our solar system. Understanding these properties will help scientists to come up with more accurate models explaining planetary birth and evolution.

Geosciences, materials research, astrophysics and plasma physics as well as structural biology and superfast chemical processes - the ultimate goal being to combine the European XFEL analytic tool with the most

powerful magnetic fields currently available or experimental options of optical laser systems is to glean new insights into previously hidden processes within matter and materials. Thanks to the Helmholtz Senate's June 24, 2015, decision, the HIB stations will become reality. The final decision for the financial support remains now with the funding bodies on the federal and state level.

Provided by Helmholtz Association of German Research Centres