New scientific opportunities for studies of matter at extreme conditions at the European XFEL

Sakura Pascarelli

European XFEL, Holzkoppel 4, 22869, Schenefeld, Germany

sakura.pascarelli@xfel.eu

In the past decade we have seen very important developments in the field of accelerator based X-ray user facilities, with the advent of 4th generation synchrotron sources and MHz rate free electron lasers. The first hard X-ray free-electron laser, LCLS (US) became operational in 2009 and over the last decade four additional hard X-ray FELs have begun user operation. Among these, the Eu-XFEL is the first high photon energy FEL powered by a superconducting accelerator, leading to an increase of more than 2 orders of magnitude in the number of delivered photon pulses per second to the sample. A unique feature of X-ray FELs is the combination of the extremely short (fs) photon pulses with the short (Ȧ) wavelengths of hard x-rays produced. These relatively new user facilities are opening novel avenues in the investigation of fundamental processes in many areas of science, from physics to chemistry, biology and materials science, because they allow investigation of matter at the time scales of electron and nuclear dynamics (down to fs), with chemical selectivity and bulk sensitivity.

After many years of construction, user operation at the Eu-XFEL ramped up gradually, and between 2017 and 2019 six instruments were delivered to the user community and are now operational. In the first part of my presentation I will briefly introduce the present performance of the facility in terms of electron and photon beam characteristics and provide an overview of recent science highlights. In the second part, I will focus on the High Energy Density (HED) instrument, a unique platform for experiments combining hard X-ray free-electron laser radiation with the capability to generate matter under extreme conditions of pressure, temperature, or electromagnetic fields. HED started user operation in May 2019 and will augment its capabilities within the next years. Scientific goals include investigation of transient extreme states of matter that can be created by intense laser pulses, diamond anvil cells, or pulsed magnets. Studies cover a wide range of HED science, including planetary and stellar interiors, impact scenarios, and intense laser-matter interactions in both fundamental research and industrial applications. I will briefly describe the status of this instrument and report first scientific results.