PAUL SCHERRER INSTITUT

GFA and SwissFEL Accelerator Seminar

A laser-cooled electron source for single-shot femtosecond X-ray and electron diffraction

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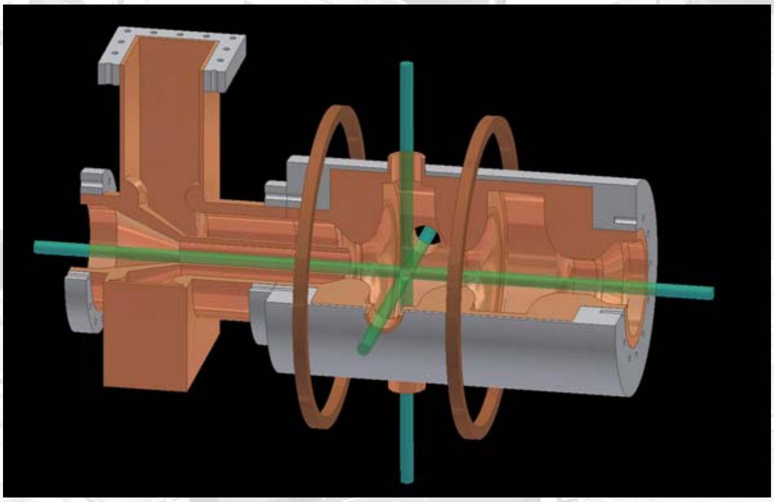
Dr. Jom Luiten
Eindhoven University of Technology,
Eindhoven, Netherlands

In 2009 the first hard X-ray Free Electron Laser (XFEL) has become operational – LCLS at Stanford University – which enables recording the full diffraction pattern of a tiny protein crystal in a single, few-femtosecond shot. This is an enormously important development but it requires a large-scale facility and investments at the national, if not the international, level. For reasons of size, costs and accessibility of the setup a small-scale XFEL, affordable by a university laboratory, would be highly desirable.
A promising route towards a small-scale XFEL is the development of low-emittance electron sources, which enable lasing at reduced electron energies. We have developed a new, ultracold pulsed electron source, based on near-threshold photo-ionization of a laser-cooled gas. The source is characterized by an effective electron temperature of ~10 K, almost three orders of magnitude lower than conventional sources. This should enable normalized RMS emittances 1-2 orders of magnitude lower than photocathode sources, at comparable bunch charge. I will discuss the properties of this new source and the possible implications for XFELs.
Another route we are investigating is to use electrons directly. Electrons and X-rays both enable the study of structural dynamics at atomic length scales, yet the information that can be extracted by probing with either electrons or X-rays is quite different and, in fact, complementary. A pulsed electron source with the XFEL capability of performing single-shot, femtosecond diffraction would therefore be highly desirable as well. The primary obstacle facing the realization of such an electron source is the inevitable Coulomb expansion of the bunch, leading to loss of temporal resolution. We have developed a method, based on radio-frequency (RF) techniques, to invert the Coulomb expansion. We will report on the first experiments demonstrating RF compression of 0.25 pC, 100 keV electron bunches to sub-100 fs bunch lengths. We have used these bunches to produce high-quality, single-shot diffraction patterns of poly-crystalline gold. By combining the laser-cooled, ultracold electron source with RF acceleration and bunch compression techniques, single-shot, femtosecond studies of the structural dynamics of macromolecular crystals will become possible with electrons as well.



Artist's impression of a laser-cooled RF photogun.

Contact: Romain Ganter (5279)