M.a.r.i.X. : an inter-Dipartimental program for the University of Milan future Scientific Campus in the Expo area

Multi-disciplinary Advanced Research Infra-structure with X-rays
Macchina Analitica per Ricerca Inter-disciplinare con raggi X

A recent agreement between the Rector of University of Milan and the President of INFN approved the preparation of a Conceptual Design Study for an advanced research infrastructure, to be located inside the future Scientific Campus of UniMi at the Milan-Rho Expo area, based on an analytical machine capable to deliver advanced photon beams of two cathegories: fully coherent Free Electron Laser X-ray beams in the 1-5 keV energy range with ultra high repetition rate up to 1 MHz, and Compton mono-chromatic X-ray beams of up to 150 keV energy with high fluxes, up to 10^{13} photons/s.

The rationale of the FEL source is to serve time-resolved spectroscopies with coherent X-rays with individual pulses not exceeding the space charge regime (high density excitation threshold) that nowadays imply a $10^{-3}/10^{-4}$ attenuation of X-ray beams at e.g. SACLA, but gaining 4-5 orders of magnitude in repetition rate to the benefit of statistics. Such source (10^{8}-10^{9} photons/shot at up to 1 MHz) is not available today at X-FELs (either normal conducting and limited to 30-120 Hz or superconducting at 27.000 pulses/second in 10 Hz macro-bunches of 4.5 MHz micro-bunches). High longitudinal coherence will enable pump-probe methods at 10-100 fs accuracy, and with high statistics. Such source will fill in the XAS/XMCD (with polarization control from quarter-wavelength blades or undulators) and bulk photoemission to become highly efficient probes of matter at the nanoscale but in bulk environments, like buried interfaces of interest in materials science, or biological matter in physiologic environment, or catalysers at work. The novel source will therefore create absolutely novel conditions for experiments that cannot be performed satisfactorily at the present and foreseen sources based on storage rings or SASE-FEL.

The rationale of the high-flux Compton Source is to enable advanced radiological imaging applications to be conducted with mono-chromatic X-rays. These range from higher sensitivity in mammography to higher contrast in edge enhancement base radio-imaging with phase contrast, to selective radio-theraphy with Auger electrons triggered inside tumoral cells by mono-chromatic photon beams. Many of these clinical applications (and more) are discussed in the document “*BriXS: Expression of Interest*”, attached to this web page.

MariX will be based on a Super-conducting Linear accelerator coupled to two kinds of “radiators” capable to convert part of the kinetic energy of electrons into photons: a short period (mm scale) magnetostatic undulator for the FEL source and a high power optical Fabry-Perot cavity for the Compton Source. The high average electron beam current (several milli-A), coupled to high brightness (i.e. high phase space density) of the electron beam, is mapped into the high flux X-ray beam property, coupled to high mono-chromaticity and tunability with full control of the X-ray beam polarization: in the FEL radiation beam, thanks to the collective coherent amplification mechanism of radiation emission typical of high gain FELs, the X-ray beam exhibits also a very high degree of temporal and transverse coherence. The Compton Source will use a push-and-pull energy recovery scheme of the low energy (50-80 MeV) electron beam, while the FEL will be based on a GeV-class single pass Super-conducting Linac operated in CW mode, in order to achieve up to 1 MHz effective repetition rate.

The know-how concerning all these enabling technologies is uniquely present at the Department of Physics of UniMi and at INFN Sezione di Milano, thanks to many research groups with outstanding expertise in the critical fields like high power optical cavities, high gradient super-conduncting RF cavities and cryostats, X-ray beam lines and detectors, and design/study of FEL, Compton Source and photonic collider physics.

We thus have a unique window of opportunity to develop a challenging project like MariX, with the ambition to integrate several expertise and research/technology fields to build an advanced research infrastructure for the future Scientific Campus of UniMI.

Milan, Sept. 8th 2017