Istituto Nazionale di Fisica Nucleare

UNIVERSITÀ DEGLI STUDI DI MILANO

BriXSinO

Brilliant source of X-rays based on Sustainable and innOvative accelerators

Un acceleratore di elettroni innovativo verso la frontiera dell'alta intensità sostenibile, per i futuri acceleratori di particelle di larga scala, e per applicazioni avanzate con raggi X mono-cromatici e radiazione THz coerente

Foreword

BriXSinO is a demonstrator of a new acceleration mechanism – two way in the same Linac (à la MariX), pursuing at the same time research of beam and machine operation in E.R.L. (Energy Recovery Linac) mode, following the original Maury Tigner's configuration of opposite way, dog-bone recirculation. BriXSinO's mission is the demonstration of high peak and average brightness beam generation, acceleration and manipulation with large energy sustainability, as requested by the high intensity frontier. Energy sustainability implies developing accelerators with large efficiency in transforming AC power into electron beam power: most Linacs do not overcome a few percent in efficiency – BriXSinO aims at achieving efficiencies larger than 20%. Besides such a primary mission, that is in the mainstream of future strategies for large scale particle accelerators, BriXSinO will offer unique radiation beams to users of X-rays and THz, thanks to the very large expected electron beam power/brightness.

Due to constraints in the footprint available at LASA's site, and budget/resources limitations typical of a demonstrator, BriXSinO will be restricted to modest beam energy, below 50 MeV in ERL mode, and 90 MeV in two-way mode, a minimum requirement in order to conceive a machine set-up composed of multiple accelerating sections, operated with Super-conducting CW RF cavities, within a configuration capable to effectively test two-way and E.R.L. operation modes.

Nevertheless, the beam power achieved is expected to reach up to 250 kW, carried by a CW 5 mA - 50 MeV electron beam, that is recirculated by a proper arc-shaped beam transport line, and decelerated through the main SC Linac back down to the injector beam energy, at about 5 MeV. The challenge is to generate, accelerate, manipulate, characterize, deliver to users and recover back such a large beam power, at the same time reaching the high phase space density (*i.e.* peak brightness) requested by the Compton source and the THz FEL operation. Such a task implies reaching normalized transverse emittances below 1 mm·mrad, together with energy spreads below 0.1%, and time and pointing stabilities typical of high brightness Linacs. These are in fact minimum requirements on beam quality

requested to drive either I.C.S. (Inverse Comtpon Scattering sources) or Free Electron Lasers (FEL): the great advantage of ERLs, compared to storage rings, is the full accessibility to beam phase space for experiments, married to beam power levels typical of storage rings, that are not achievable in standard Linacs.

BriXSinO's electron accelerator would not reach his missions without a photonic machine based on a very high phase-stability laser system, capable to pump the optical Fabry-Perot cavity of the Compton source and, at the same time, drive the injector photo-cathodes with CW beams with up to 100 MHz rep rate. An ultra-stable kW-class fiber laser is the core of the photonic machine, to drive the Fabry-Prot cavities up to MW-class stored power level and 10 mA-class electron beams delivered by photo-cathodes. The integration between the two - electron and the photonic - machines is essential in BriXSinO.

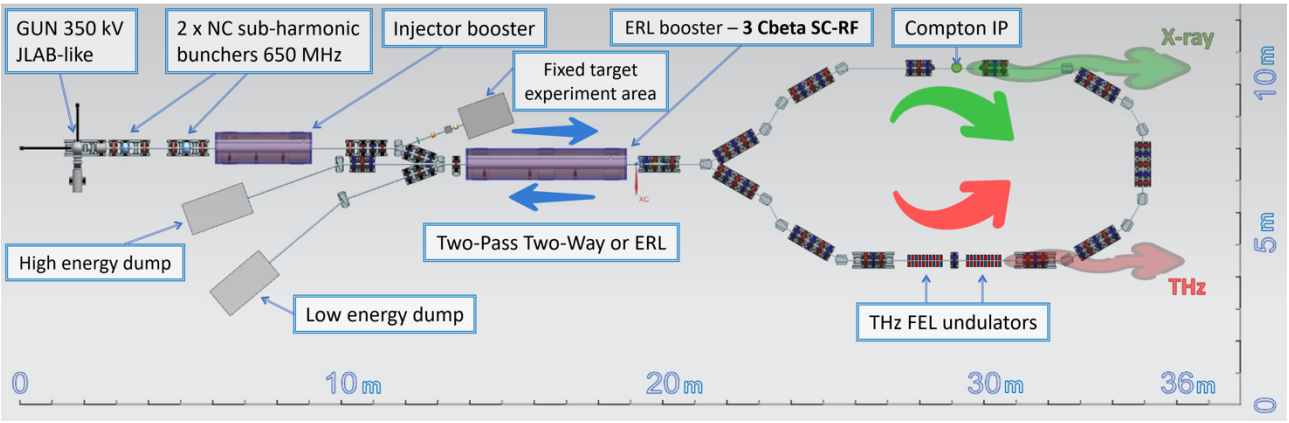

Figura 1. BriXSinO's fucntional schematics

Phase stabilities performances up to the level of the laser optical carrier will allow full synchronization of the electron beam with radiation beams delivered to users. This would allow experiments with fully synchronized mono-chromatic X-rays from the Compton source with THz beams from the Free Electron Laser oscillator.

Dual color X-rays up to 35 keV are also planned to be generated in the Compton source by a system of twin shiftable Fabry-Perot optical cavities, that was conceived, developed and succesfully tested for the first time in the context of the R&D acitivy associated to the preparation of this TDR. This innovative and new technique will allow two and three-dimensional breast radiography by exploiting dual-energy flashes and K-edge subtraction or speckle-based Phase Contrast Imaging.

Fully coherent kW-class THz beams generated by the FEL oscillator cavity will also be available, opening a new unexplored range of user experiments with imaging methods from 6 to 30 THz, with applications to medical imaging, molecular spectroscopy and remote mesoscopic morphological characterization of materials. The peculiarity of having two synchronized radiation sources at two widely different wavelengths (THz and X-rays) allows extremely interesting and advanced pump and probe experiments: simultaneous operation of the Compton source and the THz FEL is a unique capability of BriXSinO's recirculation arc and BriXSinO's dog-bone ERL operation mode.

Last but not least, a dedicated fixed target beam line, carrying an intense beam of up to 10 MeV energy and up to 5 mA average current, will enable experiments in the flash-therapy domain, as well as new positron source investigations in conjunction with Quplas experiments and scientific case, aiming at generate ultra-intense very collimated beams of positrons to conduct fundamental research also with positronium.

See below the list of other Universities and Institutions participating in the preparation of this Technical Design Report.

Politecnico di Milano, Milano

Università di Napoli Federico II, Napoli

Università degli Studi di Ferrara, Ferrara

Università degli Studi "La Sapienza", Roma

Istituto di Ricovero e Cura a Carattere Scientifico Ospedale San Raffaele, Milano

ASST Grande Ospedale Metropolitano Niguarda, Milano

Polo Ospedaliero, DGWelfare, Regione Lombardia, Milano

CNR - Istituto di Fotonica e Nanotecnologie, Milano

CNR - Istituto di Scienze Applicate e Sistemi Intelligenti, Napoli

INFN - Sezione di Ferrara

INFN - Laboratori Nazionali di Frascati

INFN – Sezione di Napoli