Laboratory Astrophysics Using Intense Ion and Photon Beams Generated by Large-Scale Accelerator Facilities in Korea

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Several large-scale accelerator facilities are operational or under construction in Korea, such as the Korea Multi-purpose Accelerator Complex (KOMAC), the Pohang Accelerator Laboratory X-ray Free Electron Laser (PAL-XFEL), and the Rare Isotope Science Project (RISP). These accelerator projects open up new opportunities in basic science researches in Korea, and provide excellent platforms particularly for laboratory astrophysics.

The KOMAC project [1] started in 2002 and completed the linac commissioning in 2013. The KOMAC linac consists of a 50-keV proton injector, a 3-MeV four-vane RFQ, and a 100-MeV drift tube linac (DTL). The RF frequency is 350 MHz and the maximum beam pulse current is 20 mA. So far, two beamlines are available for users. One is located at the end of the 20 MeV DTL and the other at the end of the 100 MeV DTL.

The PAL-XFEL project [2] started in 2011 and is currently under commissioning. The PAL-XFEL will have a dog-leg branch line at 3-GeV point of the linac for two soft X-ray undulator lines, and three hard X-ray undulator lines at the end of 10-GeV linac. A 1.6-cell type photocathode RF gun is used to inject 0.2 nC of electron beam pulse with 120 Hz repetition rate. The main accelerating structure is an S-band normal conducting linac.

The RISP project [3] will be composed of a 70 kW proton cyclotron as a low-power ISOL driver, an 18 MeV/u linac for ISOL post-accelerator and a 200 MeV/u main linac for high-power ISOL and IFF driver. The main driver linac named RAON will accelerate all elements up to Uranium with beam power up to 400 kW. To maximize the average currents of the primary beam on target, continuous wave (CW) operation is preferred, and therefore superconducting RF (SCRF) technology has been adopted for the linac design.

The laboratory astrophysics is a new emerging field of basic sciences, and has tremendous discovery potentials. The laboratory astrophysics investigates the basic physical phenomena in the astrophysical objects in controlled and reproducible manners, which has become possible only recently due to the newly-established intense ion and photon beam facilities worldwide. In Korea, however, no concrete laboratory astrophysics program has yet been established within the scope of the accelerator projects introduced above.

In this work, we present several promising ideas for laboratory astrophysics programs that might be readily incorporated in the accelerator projects in Korea. For example, spectroscopy experiments using Electron Beam Ion Trap (EBIT) and intense X-ray photons from the PAL-XFEL can be performed to explore the fundamental processes in high energy X-ray phenomena. Measurements of nuclear reaction rates relevant to rare isotopes by utilizing the RISP facility will enable us to investigate the effect of reaction rates on explosive phenomena around the astrophysical compact objects.

In many violent astrophysical events, the energy density of matter becomes so high that the traditional plasma physics description becomes inapplicable. Generation of such high-energy density states can be achieved by using the intense photon beams available from the PAL-XFEL. Understanding the interactions between the intense photons and over-dense plasmas (such as those produced in solid targets or foils) will be useful not only for the astrophysics, but also for the study of laser acceleration of protons and ions.

On the other hand, while not directly connected with the astrophysics, we also note that the low-flux proton beams available from the KOMAC facility can be used to provide space radiation environment, which is essential to test the performance of detectors for observation satellites.

References

[1] KOMAC web page, http://www.komac.re.kr.
[2] PAL web page, http://pal.postech.ac.kr.
[3] RISP web page, http://www.risp.re.kr.