# FORUM on Superstrong Fields and High Energy Physics

Toshi Tajima* and Gerard Mourou¶

** LLNL, Livermore, CA 94551, USA*
*¶ CUOS, University of Michigan, Ann Arbor, MI 48109, USA*

The Livingston chart of the evolution of the accelerator energy as a function of time is just one testimony of how spectacular the accelerators and high energy physics have progressed in the last century. Equally impressive in its advance has been that of lasers, though its inception was a quarter century younger. These explosive developments and successes in the respective fields have felt the presence or progress of the other in recent years in some of specific occasions and endeavors. Nonetheless, these two fields so far have marched relatively independently from each other. We are perhaps now at a crossroad where the facilitation of the one field by the other may become mutually stimulating and even more profitable for the future progress. At the Varenna Conference on Superstrong Fields in Plasmas, we held a Forum on applications of intense lasers to high energy physics (HEP). Five panelists with a broad range of expertise from laser physics to plasma physics to high energy physics discussed this emerging cross-road of both fields in front of the Conference participants: T. Tajima, chair, G.Mourou, D.Habs, K.Nakajima, and P. Chen.

The new technology based on lasers has a potential to bring in (1) extremely high accelerating gradient and (2) very bright beams.
With the adoption of lasers, it was suggested that low emittance (in another word, very high quality and thus bright) beams of particles may be generated, which may be injected into high energy accelerators. Such bright injection beams may also help the performance of an accelerator based laser called 'Free Electron Laser', in turn, which is touted to be employed with unprecedented brightness, clarity and resolution (in ~Angstrom) as a probe of material and biological science. The high accelerating gradient has been one hallmark of laser driven acceleration (routinely exceeding by several orders of magnitude over the conventional methods, but only as a proof-of-principle fashion so far), but its control of quality of beams has lagged so far. This emerging new capability with intense lasers with its 'greenness' inherent in a new technology may perhaps be best utilized with some combination with the existing more established high energy physics technologies. This way, one can combine the strengths of two different technologies in a fashion to complement each other using their respective strength. Laser-cooled crystalline beams, which have been discussed at the Forum as a first experimentally demonstrated case, will bring in extremely

CP611, *Superstrong Fields in Plasmas:* Second Int'l. Conf., edited by M. Lontano et al.

bright beams to HEP accelerators in a different method. As another application of the large gradient of laser driven accelerators, to prompt accelerate unstable particles such as pions and muons has been suggested. Such capability will help increase the quality of beams of muons and even neutrinos in the future.

The Forum discussed the new vista of the laser power leap, which is dubbed as 'en route to Zettawatt' during the conference, reminiscent of the paper 'en route to Petawatt' by Mourou a generation ago when the new technology chirped pulse amplification (CPA) was invented. With the current development of large energy lasers such as NIF (National Ignition Facility) at Livermore and LMJ(Laser Mega Joule) in France in combination of CPA and other technology will allow us an opportunity to make this leap in laser power in several orders of magnitude. Though the current intense lasers are already relativistic, these new lasers will push us into ultrarelativistic regimes. A class of new physics associated with accelerating particles to high energies, sometime to extreme high energies, has been discussed. For example, extreme high accelerating gradient of laser causes equivalent extreme high gravity, which in turn may serve to explore strong gravity effects. This includes studies to test the strong limit of Einstein's Equivalence Principle of General Theory of Relativity and even to probe the presence of (gravitationally) curved spacetime horizon that lies within a finite distance. Some of these signatures may be manifested in a phenomenon of the so-called Unruh radiation (a sister to the Hawking radiation near a black hole). There is also a potential to detect the 'leakage' of extra-dimensions of quantum gravity if the gravitational interaction 'leaks' out sufficiently far beyond the shrunken horizon.

In spite of these far-out fundamental science frontiers that extreme high field lasers may bring in, there have been also a substantial set of suggestions that may be realized in a nearer term in collaboration with the existing high energy scientists at various facilities. Mentioned are:
(a) laser electron injector with ultra-low emittance, (b) laser ion injector beam sources, (c) prototype laser-based next generation accelerators, (d) prompt acceleration of unstable particles, (e) spin-polarized positrons, (f) testing cosmic acceleration in laboratory, and (g) combination of high laser field and high energy beams such as gamma-gamma collider, and other energy boosting ideas.

In the end there was a suggestion to draw a resolution by the Forum participants to call for a greater interaction with the high energy physics community, which read: "In order to facilitate the activity of promotion of the development of near-term projects relevant to High Energy Physics Laboratories, we form an ad hoc committee to advance the liaison between HFS (high field science) and HEP communities and, if necessary, to communicate with the leaders and management of HEP labs to enhance this relation. This committee can also sensitize our understanding of the needs of lasers that are necessary to fulfill such developments. Any interested person in this Forum/Conference is invited to join this committee."

*The work was in part supported by US DOE W-7405-ENG-48 and NSF.