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Laser-Plasma Accelerator Development at the BELLA Center

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The BELLA Center [1] has been performing forefront research on laser-plasma accelerators (LPAs) for over two decades. The central thrust is R&D towards a future plasma-based linear collider [2], funded by DOE HEP. The main objectives of this research [3] are the development of LPA modules at the 1-10 GeV level and the staging (coupling) of LPA modules. It also includes research on improving the electron beam quality produced by an LPA, optimizing LPA modules at the 10 GeV level, the efficient coupling and staging of LPA modules, theoretical studies of an LPA-based collider, and near-term applications of LPA technology, such as compact light sources [4]. High-efficiency, high-average power lasers are essential to many applications, including colliders. The BELLA Center has an active program on the development of high efficiency, high average power lasers based on fibers as well as near term kHz systems [5]. This forms an integrated research program addressing the U.S. Advanced Accelerator Roadmap for future colliders [6].

Center research is an integrated activity consisting of theoretical, computational, and experimental components. The BELLA Center has published over one hundred refereed journal papers that have received thousands of citations. The BELLA Center has achieved many experimental "firsts", including the first demonstration of the production of high-quality (narrow energy spread and low divergence) electron beams from an LPA in 2014 (the "Dream Beam" issue of *Nature*) [7] and, more recently, the world record for the electron energy of 8 GeV from an LPA [8].

The current laser systems at the BELLA Center include the BELLA PW laser (40 J, 35 fs, 1 Hz) and two independent 100 TW laser systems (4 J, 35 fs, 5 Hz). The experimental facilities also include shielded caves, clean rooms, target chambers, and a large array of diagnostics. The BELLA Center is actively carrying out two upgrade projects. The first is to install a second beamline on the BELLA PW laser to allow to the delivery of two synchronized pulses on target, enabling experiments on staging of LPA modules at the multi-GeV level, as well as a variety of other experiments. The second project is to extend the original BELLA PW beamline to include a short focal length geometry in a new target chamber. This will enable experiments at ultrahigh intensity ($>10^{21}$ W/cm^2) for a variety of experiments, including ion acceleration, high-field laser-particle interactions, and generation of nonlinear wakefields. The BELLA Center is also pursuing a new facility, kBELLA [9], consisting of a 1 kHz, few J, 30 fs, high-average power laser and a highly shielded cave, for the demonstration of a high rep-rate, precision LPA that is required to advance performance toward collier goals and applications.

The BELLA Center functions as a collaborative research center, where research is carried out by the BELLA staff together with select researchers that share common goals and interests. The BELLA Center is also part of LaserNetUS [10], in which a limited amount of laser time is made available to outside researchers through a formal proposal submittal and review process.

References

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