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Burst Intensification by Singularity Emitting Radiation: Towards Terawatt compact coherent x-ray source

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Coherent x-ray sources are indispensable in fundamental research and applications. Recent trends in development of such sources include two broad classes: km-scale accelerator-based x-ray FELs and compact laser-based sources such as x-ray lasers and atomic high-order harmonics. Fundamental limitations of conventional techniques severely hinder the development of a bright compact coherent x-ray source, especially at keV photon energies. Relativistic laser plasma [1] gives a new class of bright coherent sources [2], including high-order harmonic generation from overdense plasma surfaces [3] and reflection from relativistic flying mirrors [4].

BISER is a new phenomenon in which relativistic plasma singularities are used to obtain ultra-bright spatially and temporally coherent x-rays [5],[6], Fig. 1. Singularities are necessarily produced by multi-stream flows, which are ubiquitous in nature, such as with shock waves and jets in astrophysical and laboratory plasmas. Catastrophe theory explains the universality and structural stability of singularities, i.e., an insensitivity of their existence to perturbations. If a singularity occurs in an emitting medium, the emission from the singularity location becomes extremely intense and coherent because of constructive wave interference (N^2 effect), Fig. 1(b). This is a fundamental general effect that is applicable to any medium capable of emitting traveling waves, e.g., electromagnetic, acoustic, or gravitational.

In relativistic laser plasma driven by a femtosecond multi-TW laser the singularities of electron density emit XUV and soft x-ray radiation with a yield scalable as laser power squared [5], source size in the nanometer range [6], and attosecond duration close to the transform limit [6].

Here we present our recent experimental results obtained with the J-KAREN-P laser [7]. We demonstrated BISER in the XUV region (60-100 eV) with ~10 μJ pulse energy and >10^{12} photons/pulse. Importantly, both the spectral range and acceptance angle were limited by a small-diameter XUV mirror. Based on the angular distribution measured earlier, this indicates possibility of ~100 μJ BISER pulses emitted in a wider angle. The measured full bandwidth exceeded keV, corresponding to sub-10-attosecond transform-limited pulse duration and potentially Terawatt x-ray pulses.

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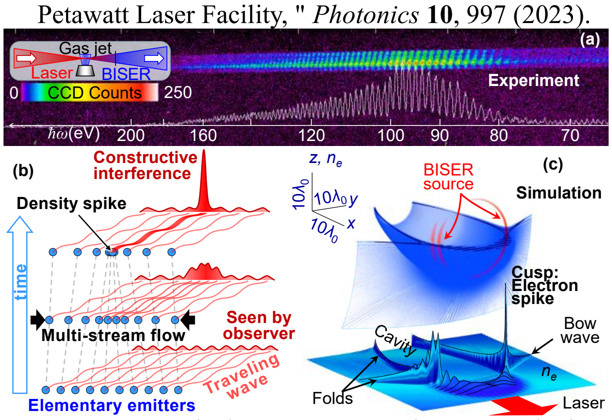

Figure 1. (a) Typical spectrum, experiment [5]; the inset shows simplified setup. **(b)** BISER principle [6]: Multi-stream flow of elementary emitters leading to the formation of singularity (density spike) and constructive interference. **(c)** 3D PIC simulation [5].