Superradiant x-ray emission in ion channels

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Betatron radiation from plasma sources stands as a promising alternative towards a compact x-ray source. Temporally coherent betatron x-rays can be generated with the Ion Channel Laser [1] (ICL), relying on the microbunching instability to modulate the bunch at the radiated frequency. Here, instead, we generalize the ICL for broadband, superradiant, off-axis emission of x-rays. We show that such radiation can be produced in plasma wakefields by modulating the particle beam at much lower frequencies (e.g. infrared) by relying on Generalized Superradiance [2]. This scheme allows arbitrarily diluted beams to radiate coherently, exploiting the optical shocks coming from superluminal beam structures. A key requirement of this scheme is then imposing a modulation with a superluminal phase velocity in a particle beam.

Through theory and Particle-In-Cell simulations, we show that it is possible to achieve such modulation in the wakeless regime, where the wakefield bubble extends past the plasma boundaries, leaving a pure ion channel behind. We do this by using low-intensity lasers ($I < 10^{18}$W/cm^2) to seed the modulation in the electron beam and by matching the betatron frequency to the laser frequency in the electron's frame of reference. In a co-propagating geometry, a Bessel beam co-propagates with the electron beam. Because the modulation moves faster than c, beam electrons produce a train of superradiant optical shocks at the Cherenkov angle. Figure 1 shows the spatiotemporal radiation profile obtained with this setup using the Radiation Diagnostic for OSIRIS [3]: ultra-intense, attosecond light bursts.

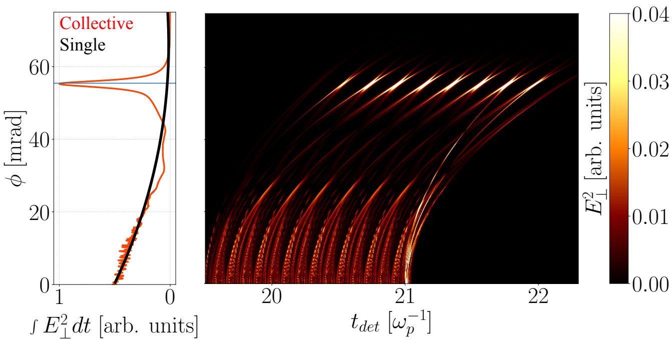

Figure 1: *Radiation from the modulated beam at a detector (left) and its time-integrated specturm (right). The black line is the spectrum of a single particle.*

References

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