Intense Coherent THz Pulses from the NSLS Source Development Laboratory Photo-injected Linac and Applications in Ultra-fast Material Dynamics

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Abstract:

For much of the history of coherent THz pulse sources, their low intensity has limited their application to the role of probing materials. The development in recent years of higher energy THz pulse sources has enabled their practical use for photo-exciting - or “pumping” - a sample such that non-equilibrium dynamics can be studied.

In contrast to conventional laser pumping, where the source is typically narrow-band and the pulse contains multiple cycles of the E-field, a coherent THz pulse can have a single-cycle such that a sample's response corresponds to the impulse delivered by the electric or magnetic field on a picosecond or faster time scale. Examples of scientific relevance include switching behavior in ferroelectric and ferromagnetic materials, dielectric breakdown, and critical current dynamics in superconductors.

The ultra-short, high charge bunches in a photo-injected linac can serve as such a source of THz pulses, possessing some unique qualities not presently available in laser-based sources. For example, while intense mid-infrared (10's of THz) pulses with field strength exceeding 1 MV/cm can now be produced by difference frequency generation (DFG), such pulses are usually not single-cycle. Additionally, the amplified laser pulses needed for DFG limits the pulse repetition frequency such that a high average power is not easily achieved. As has been shown successfully at the Jefferson Lab energy recovery linac (ERL), photo-injected linacs can be operated at 10's of MHz repetition rates.

In this presentation I will review the THz source characteristics for the Source Development Laboratory (SDL) photo-injected linac in the Photon Sciences directorate at Brookhaven Nat'l Lab and some applications in condensed matter physics. With a bunch charge exceeding 1 nC and bunch length well below 1 ps, this linac delivers single-cycle THz pulses with energies up to 100 μJ. In addition to observing a number of novel electro-optic effects in non-linear optical crystals, we have used these pulses to excite supercurrents in a NbN thin film and observed the breakdown of superconductivity on a picosecond time scale.

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