Contribution ID: **18** Type: **Talk**

THz Generation with Accelerators

Wednesday 25 June 2025 16:50 (45 minutes)

Terahertz (THz) radiation, occupying the spectral region between microwave and infrared, has emerged as a powerful tool for applications in materials science, biology, security, and ultrafast dynamics. Accelerator-based THz sources offer distinct advantages over conventional laser-based systems, including superior pulse energy, spectral brightness, tunability, and repetition rate. This tutorial provides an overview of THz radiation generation using accelerated electron beams, with a particular focus on accelerator-based THz free-electron lasers (FELs)—among the most powerful and flexible sources of coherent THz radiation. These systems are capable of delivering both high peak and average power, with broadband or narrowband output and tunable frequencies. The tutorial will cover the fundamental physics of FEL operation, beam dynamics requirements, and the function of key accelerator components—including photo injectors, linacs, and undulators—in enabling efficient THz generation. Insights into modeling and simulation tools will also be provided and current challenges arising from the operational experience with the single-pass high-gain THz-FEL at PITZ will be discussed. Finally, future directions for the development of compact, high-repetition-rate THz FEL systems will be explored, supported by state-of-the-art examples from leading research facilities.

Summary

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Session Classification: Tutorial ”THz generation and diagnostic”

Track Classification: Tutorial: ”THz generation and diagnostics”