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Comprehensive Single-shot Diagnostics for Quantifying LWFA Beam Quality

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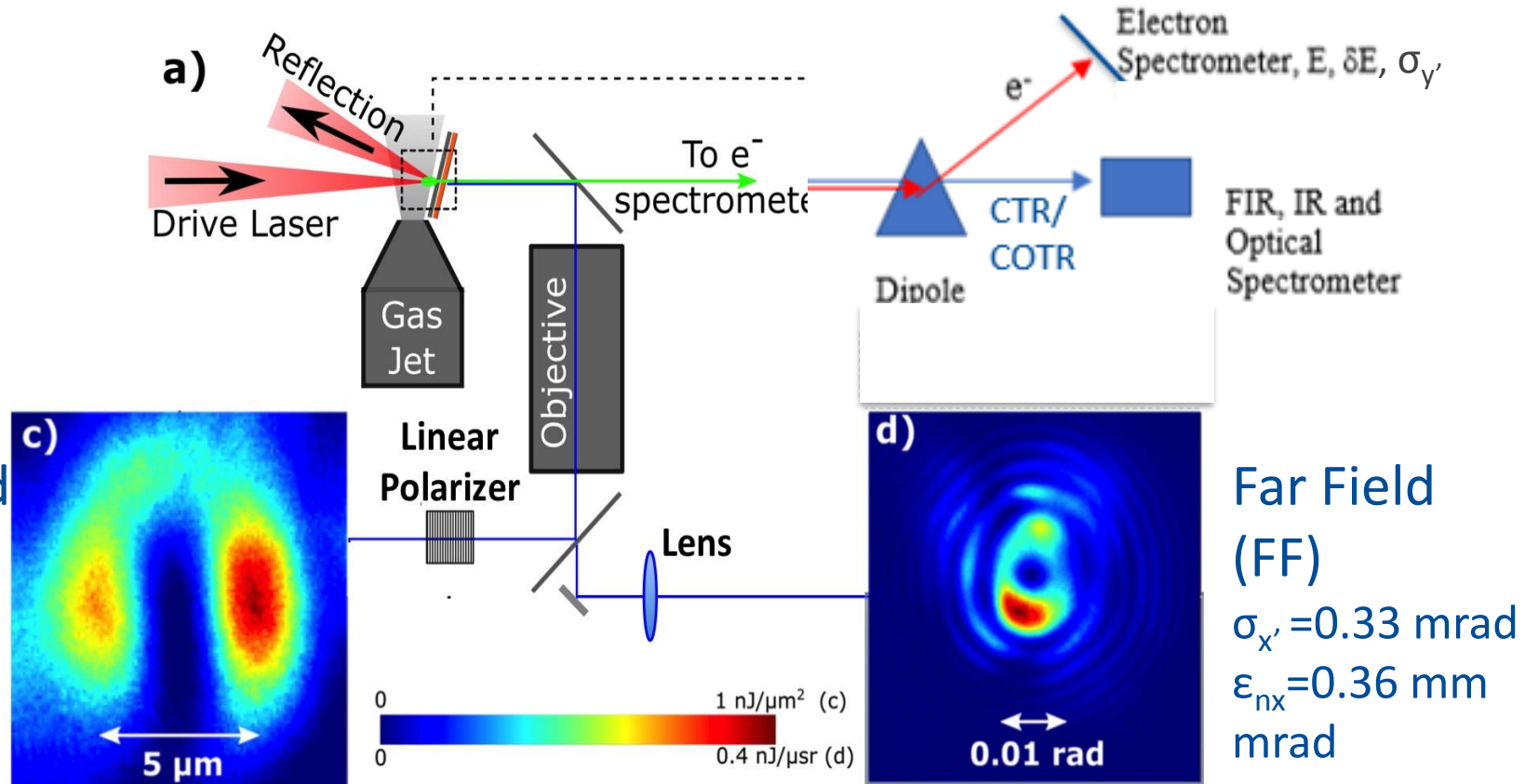
***Goals for Advanced Accelerator Diagnostics:
Single shot, minimally-invasive, high resolution**

Advanced LWFA Diagnostics with COTR

- We identified **microbunching** in subsets of the electron beam from **Laser-driven Wakefield Accelerators (LWFAs)**.
- As the beam transits the interface of the metal foil or Si mirror, coherent optical transition radiation (COTR) was generated by the microbunched electrons with **gains of >100,000 over OTR**.
- Using a COTR point-spread function model by M. LaBerge and a COTR interferometry (COTRI) model by D. Rule, we measured in single-shot the **beam size, divergence, emittance, and microbunching fraction** of the subset of electrons.
- This subset has **~10x better emittance and energy spread** than the ensemble of electrons with $\sigma_x = 2.75 \mu\text{m}$, $\sigma_{x'} = 0.33 \text{ mrad}$, and $\varepsilon_n = 0.36 \text{ mm mrad}$ with estimated <1 % energy spread.
- **Proposed a technique also for COTR spectroscopy+ divergence, energy, and energy spread of ensemble electrons.**

Schematic of LPA Experiment at HZDR

- High power laser of 150 TW at 800 nm with a pulse length of 30 fs is focused to $\sim 25 \mu\text{m}$ in a 3-mm long, N_2 -doped He gas jet. Energetic electrons are generated and then measured.



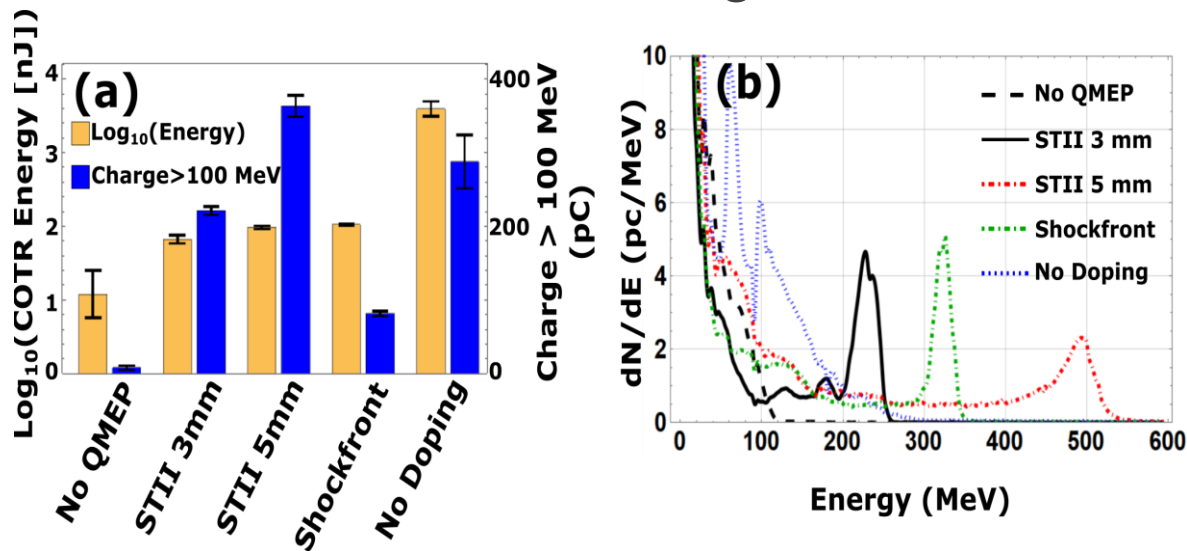
Lumpkin *et al.*, PRL July 2, 2020



COTR Techniques Apply Whenever Microbunching Occurs

- Laser-driven plasma accelerators across 4 injection schemes exhibit COTR gains. Can use techniques to improve beam quality and increased microbunching fraction.

-Quasi-monoenergetic Peak (QMEP)
-Self-Truncated Ionization injection (STII)



- Previous COTR observations in capillary-discharge injection.
- Combined single-shot techniques can guide the development of LWFA beam-quality and laser-electron effect investigations.

Lumpkin *et al.*, PRL, Suppl. M, July 2, 2020

