Coherent optical transition radiation from single-digit-femtosecond electron beam structure

QUANTUM LIGHT-MATTER COOPERATIVE

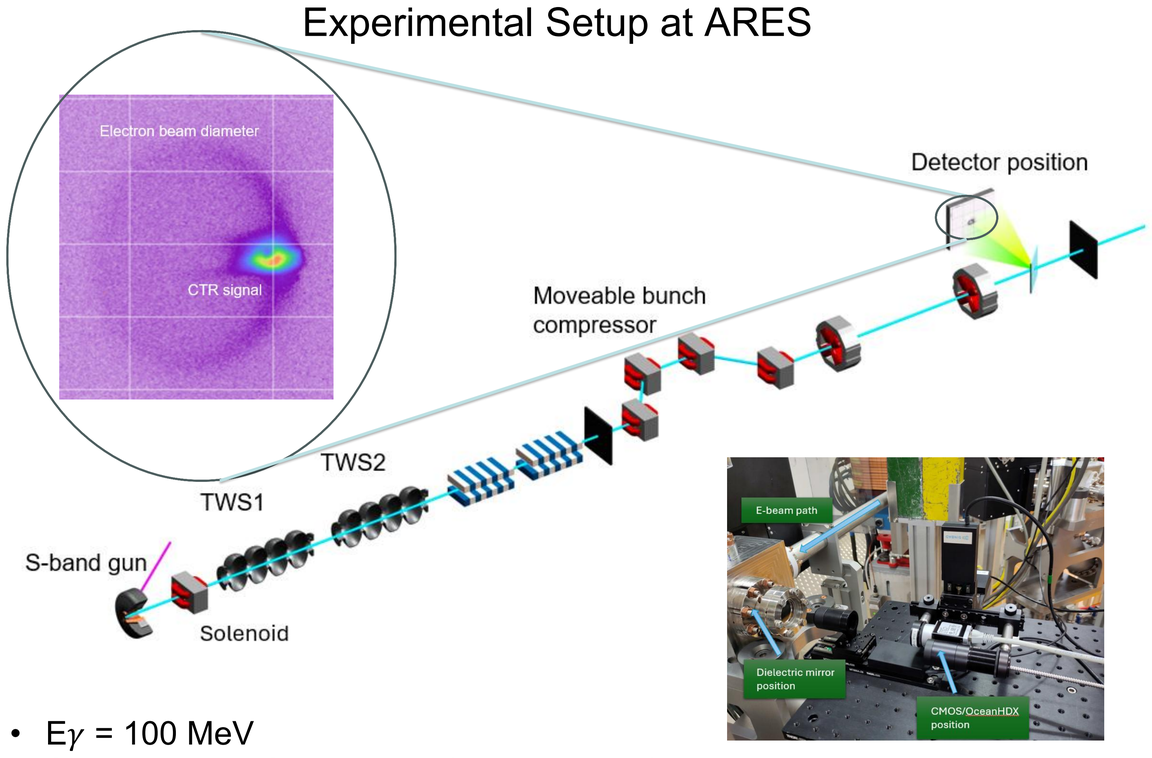
Chad Pennington[1,2], Gia Azcoitia[1], Blae Stacey[3,4], Willi Kuropka[3], Jack Rozells[1] Francois Lemery[3], Florian Burkart[3], Sergio Carbajo[1,2,5]

[1]Department of Electrical and Computer Engineering, University of California Los Angeles, Los Angeles, CA 90095
[2]Physics and Astronomy Department ,University of California Los Angeles, Los Angeles, CA 90095
[3]Deutsches Elektronen-Synchrotron DESY, 22607 Hamburg, Germany
[4] Universit¨at Hamburg, Department of Physics, 22607 Hamburg, Germany
[5] SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA

Introduction

Coherent optical transition radiation (COTR) is generated when relativistic electron bunches traverse a dielectric boundary and contain longitudinal structure on the scale of the emitted wavelength [1,2]. We present measurements of visible COTR from strongly RF-compressed relativistic electron bunches at the ARES beamline at Deutsches Elektronen-Synchrotron (DESY) [3]. Optical spectra were measured over a range of bunch charges and fitted with a coherent transition radiation model. The measurements demonstrate that RF compression alone is sufficient to generate visible coherent optical transition radiation, without undulators or externally seeded optical modulation.

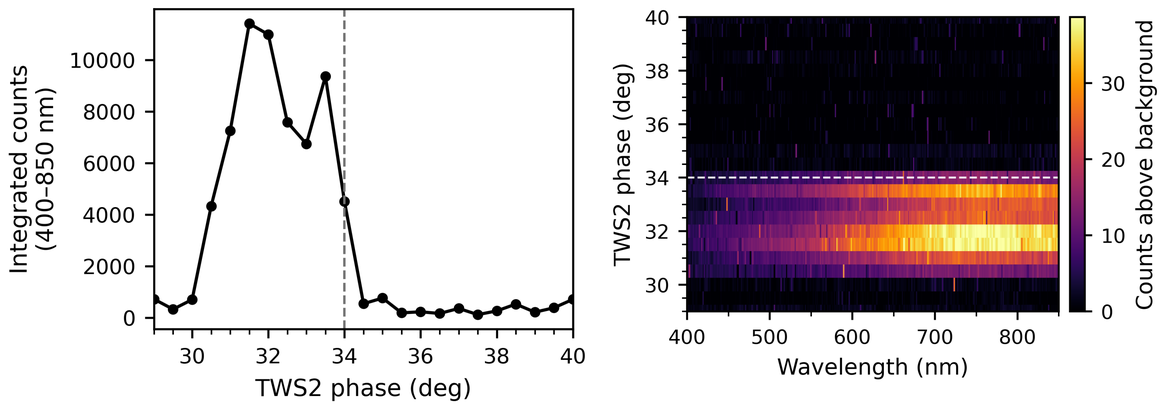
Experimental Setup at ARES



- Eγ = 100 MeV
- Spectrometer: Ocean HDX (200-1100 nm).
- RF compression via TWS2 linac phase scans.
- Transition radiation generated at a dielectric-coated silver mirror

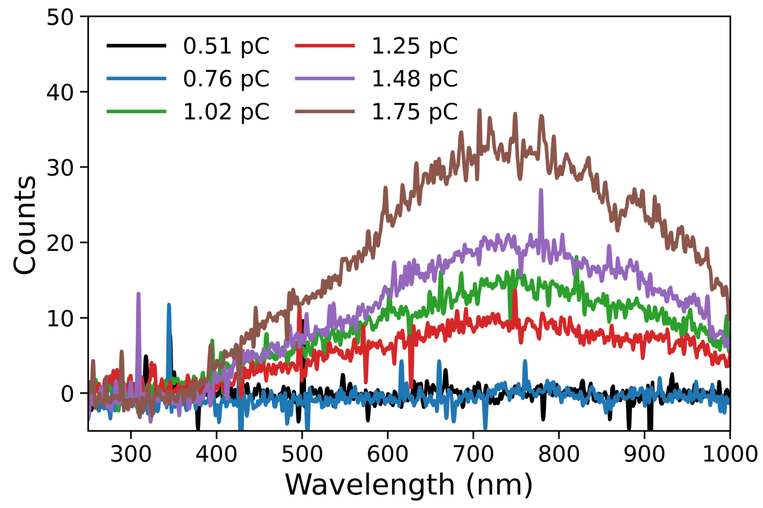
RF Phase Dependence

The TWS2 RF phase was varied to control longitudinal compression while visible CTR counts were recorded.



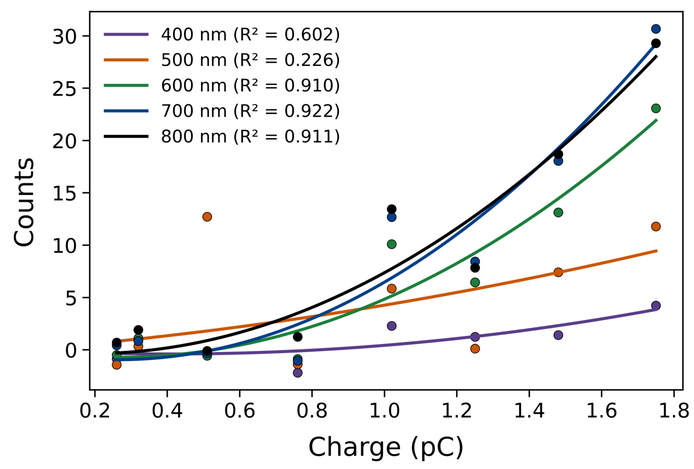
COTR is observed over a narrow range of TWS2 RF phases corresponding to maximum bunch compression.

Coherent optical transition radiation from RF-compressed electron bunches



Optical spectra acquired at various bunch charges near maximum bunch compression.

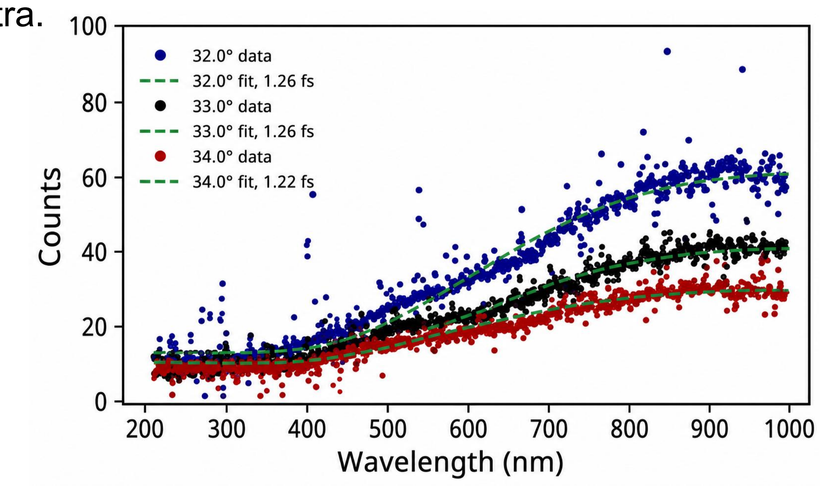
Quadratic scaling between integrated optical intensity and bunch charge is consistent with coherent emission.



The coherent spectral intensity can be expressed as

$$I(\omega) = I_{1(\omega)}\,[N + N(N-1)|F(\omega)|^2]$$

Where $I_{1(\omega)}$ is the single electron spectral intensity, N is the number of electrons, and $F(\omega)$ is the longitudinal form factor. A Gaussian longitudinal form factor was assumed when fitting the measured spectra.



Fits to the measured spectra yield a characteristic longitudinal feature of approximately 1.2 fs [4].

Summary and Conclusions

Coherent optical transition radiation (COTR) from strongly RF-compressed relativistic electron bunches was measured at visible wavelengths. The measured spectra exhibit quadratic charge scaling and are well described by a CTR model yielding a characteristic longitudinal bunch feature of approximately 1.2 fs. These results demonstrate that RF compression alone is sufficient to generate coherence at optical frequencies, establishing visible COTR from RF-compressed electron beams without undulators or externally induced microbunching.

References

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Acknowledgements

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