# Activities of the Experimental Group on Electromagnetic Processes within the FLAP Collaboration at the MT-25 Microtron

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## Introduction

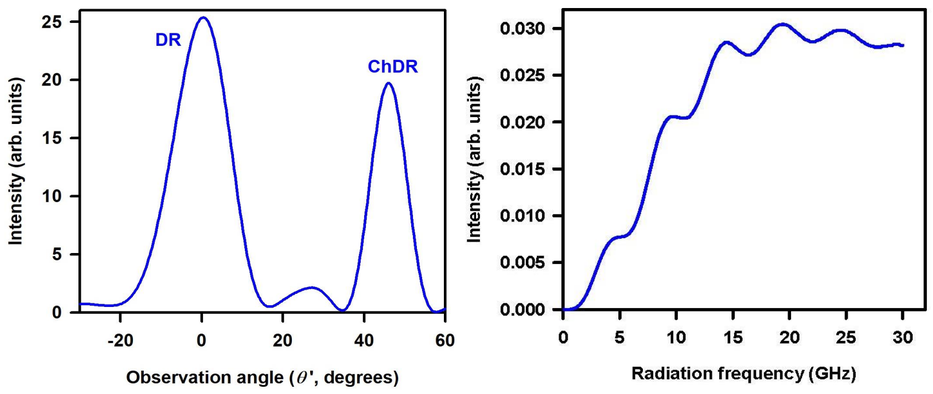
- High-energy electron beams require high-precision diagnostics.
- Coherent radiation, notably Cherenkov diffraction radiation (ChDR) [1] from electrons passing a dielectric edge, enables precise beam monitoring or intense THz generation.
- Experiments performed at MT-25 microtron as part of the FLAP collaboration by the experimental group on electromagnetic processes.

## Theoretical part of Cherenkov Diffraction Radiation

The ChDR generation condition: $\cos\theta_{Ch} = 1/(\beta n)$, where $\beta = v/c$ and $n$ is the refractive index.
Super-radiant regime of bunch train → discrete spectrum at harmonics of $f_b$.
The overall spectral-angular distribution: 1) single-electron radiation, 2) the single-bunch form-factor (which depends on the bunch length $\sigma_z$), 3) an interference term for $N_b$ identical bunches

$$\frac{d^2W}{dwd\Omega} = N^2 \frac{d^2W_e}{dwd\Omega}\left[\exp\left(-\frac{4\pi^2 f^2 \sigma_z^2}{c^2}\right)\right]\left[\frac{\sin^2(N_b\phi/2)}{\sin^2(\phi/2)}\right].$$

- Spectrum envelope (form-factor) → average microbunch length.
- Shape of spectral lines → uniformity of bunch train.
- Angular distribution and single-electron spectrum also simulated.

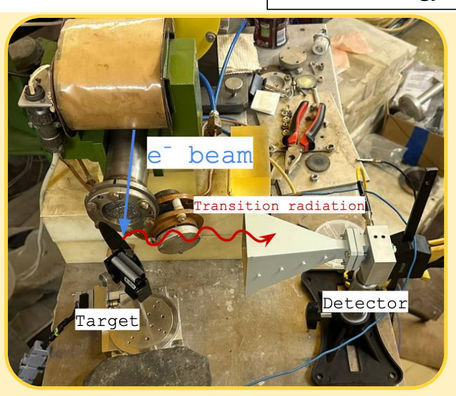



*Left: Angular distribution of polarization radiation generated by a relativistic electron from a triangular prism calculated for the ChDR freq. 19.56 GHz. Right: Single electron spectrum calculated for Cherenkov angle θ' = 46°.*

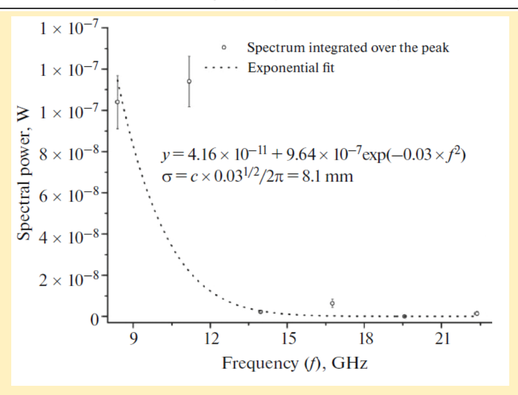
## Measurement of Coherent transition radiation

In 2024 the CTR spectra [2] were measured at MT-25 microtron. The technique for its measuring allows for longitudinal diagnostics of charged particle beams. Based on the experimental data obtained, it was possible to estimate the length of the electron bunch: ***$\sigma_s$ = 8.2 mm ± 1.1 mm***.

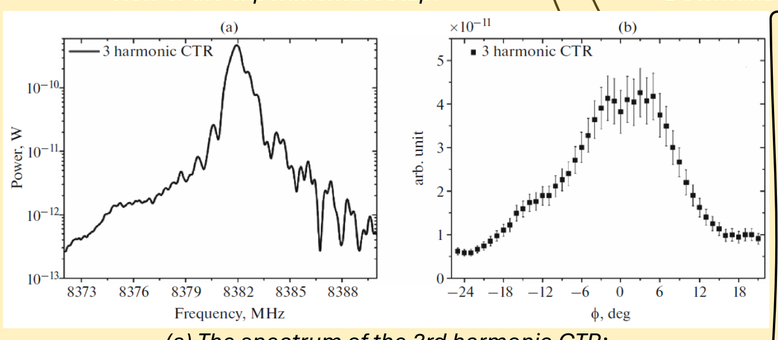
Electron energy – 10 MeV, average beam current – 10 μA, repetition frequency – 380 Hz.




*View of the experimental setup.*




*Determination of the length of the electron bunch.*




*(a) The spectrum of the 3rd harmonic CTR;*
*(b) The orientation dependence of the 3rd harmonic CTR.*

By using a formula for the form factor of a Gaussian electron bunch, we estimate the length of a bunch:

$$F_b(w,\sigma) = \left|\int_{-\infty}^{+\infty} \rho(z,\sigma) e^{-i\frac{wz}{c}} dz\right|^2 = e^{-\frac{\omega^2\sigma_s^2}{c^2}}$$

where $\sigma_s$ – rms length of the bunch, $c$ – speed of light, $\omega$ – frequency of radiation.

## Measurements of ChDR

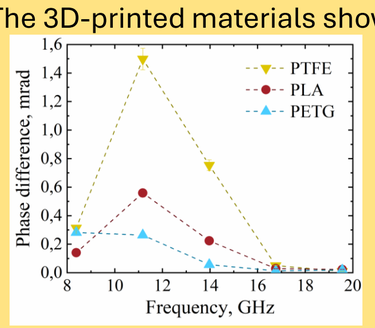
In 2025 the ChDR spectra generated by different targets were measured [3-5]. The experimentally estimated electron bunch length: ***$\sigma_z$ = 8.8 mm ± 0.1 mm***.

Electron energy – 10 MeV, repetition frequency – 380 Hz.

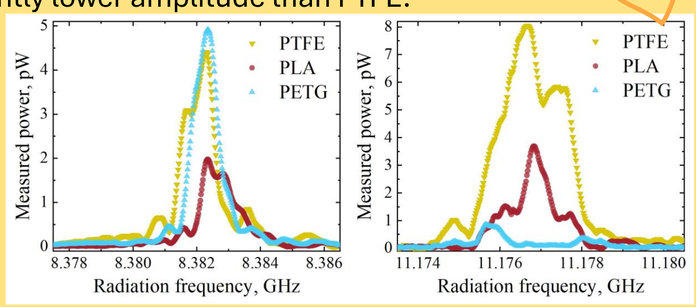
### *ChDR from 3D printed targets*

Average beam current – 20 μA.

- Experimental measurement of the ChDR spectra of three different materials.
- The 3D-printed materials show slightly lower amplitude than PTFE.




*ChDR spectra integrated over each harmonic peak for materials under the study.*

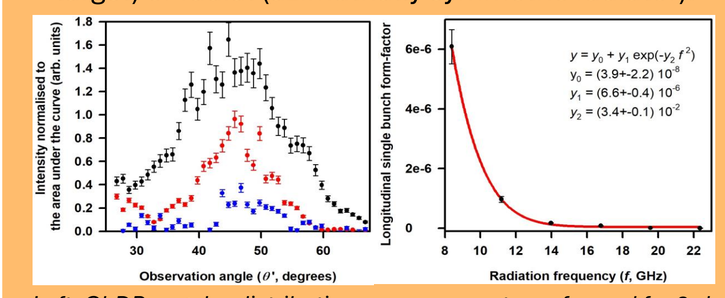



*Spectra of the 3rd (left) and the 5th (right) harmonics of ChDR generated from PETG, PLA, and PTFE radiators.*

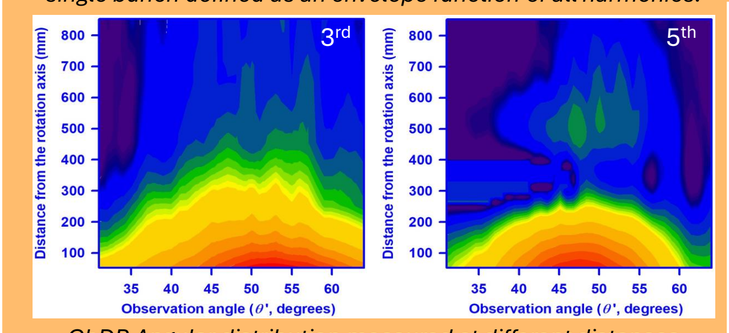
### *Coherent ChDR in super-radiant regime from PTFE target*

Average beam current – 9.5 μA.

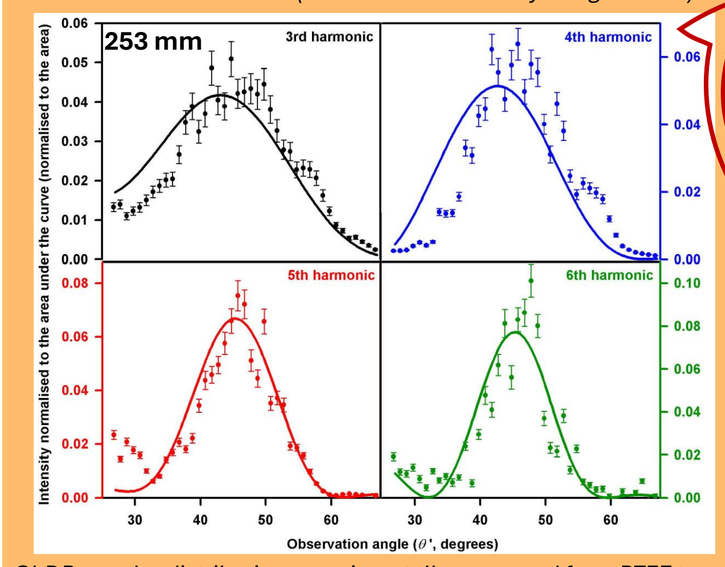
- Spatial distribution shown pre-wave zone and far-field zone.
- Polarization of super-radiant spectral lines vs. frequency investigated.
- Measured ChDR angular distributions agree with polarization current theory (pre-wave zone) → validates predictions for applications.
- Radiation is linearly polarized, rotatable: vertical (offset target) or radial (azimuthally symmetric radiator).



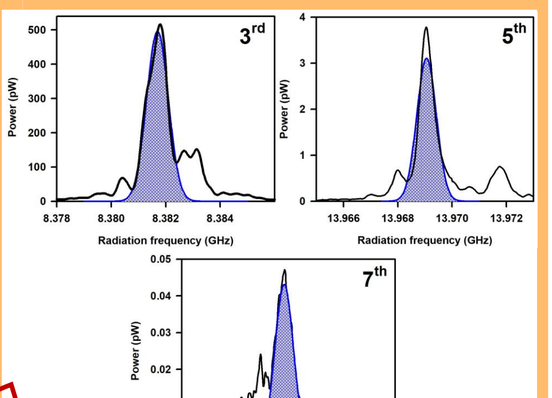

*Left: ChDR angular distribution measurements performed for 3rd, 5th, and 7th harmonics. Right: The longitudinal form-factor of a single bunch defined as an envelope function of all harmonics.*



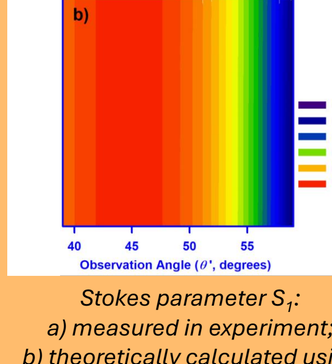

*ChDR Angular distribution measured at different distances from the axis of rotation (color scale of intensity is logarithmic).*



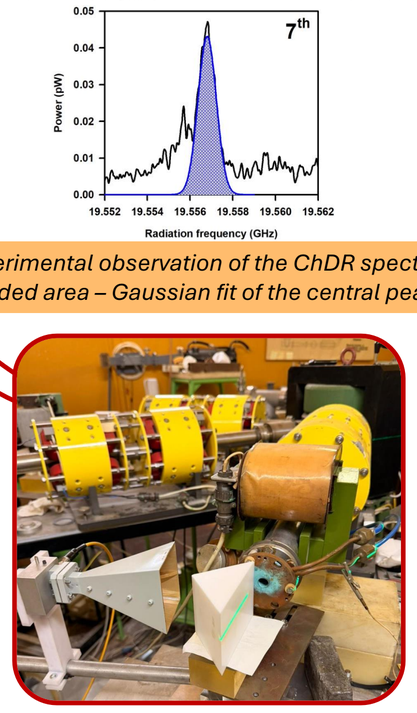

*ChDR angular distribution experimentally measured from PTFE target and theoretically calculated using polarization current approach.*



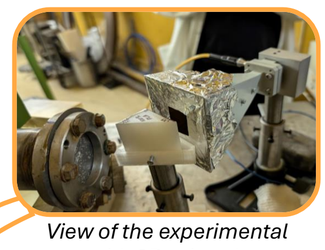

*Experimental observation of the ChDR spectra. Shaded area – Gaussian fit of the central peak.*



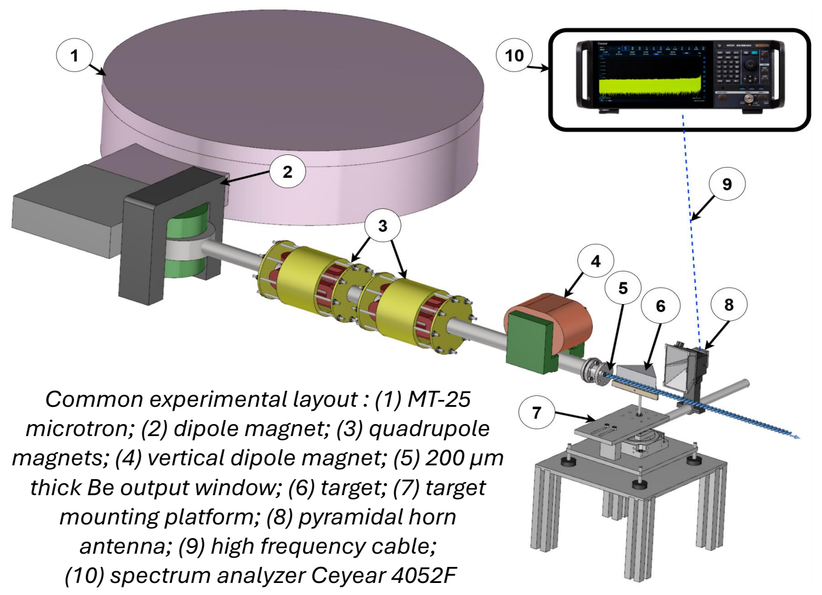

*Stokes parameter $S_1$:*
*a) measured in experiment;*
*b) theoretically calculated using polarization current approach.*



*View of the experimental setup with Teflon target.*



*View of the experimental setup with 3D printed target.*




*Common experimental layout : (1) MT-25 microtron; (2) dipole magnet; (3) quadrupole magnets; (4) vertical dipole magnet; (5) 200 μm thick Be output window; (6) target; (7) target mounting platform; (8) pyramidal horn antenna; (9) high frequency cable; (10) spectrum analyzer Ceyear 4052F*

## Conclusion

The results confirm efficient ChDR generation from both materials at the theoretically predicted angles. Furthermore, they highlight the potential of this coherent radiation for longitudinal beam diagnostics [2–5].

## Upcoming

The measurements revealed a phase slip, which will be measured in more detail in the future. Doppler effect and forward beam measurements are planned at the MT-25 microtron. The FLAP collaboration plans to conduct experiments at the LINAC-200 accelerator once the necessary permits are granted.

## Acknowledgments

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