Spectral and polarization properties of THz radiation from mm-scale dielectric capillaries with reflectors

RREPS/AGTAX 2017, 18 – 22 Sept 2017.

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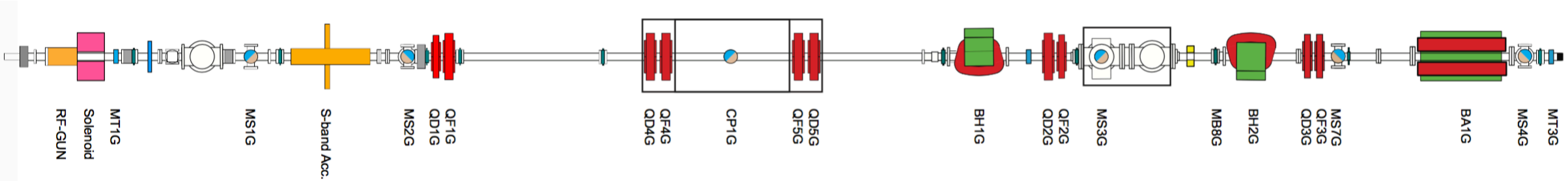
Introduction

1. Overview of LUCX facility.
2. Cherenkov Smith – Purcell radiation (ChSPR) from corrugated capillary with reflector.
    a. Experimental setup for spectral measurements.
    b. Spectral measurements for single bunch beam propagation with transverse off-set in corrugated capillary.
    c. Spectral measurements for two-bunch beam in corrugated capillary.
    d. Applications as a diagnostic tool for beam position and bunch separation monitoring.
3. Conclusions.

LUCX facility: Overview



- The Laser Undulator Compact X-ray facility (LUCX) is a multipurpose linear accelerator which was initially constructed as an RF gun test bench and later extended to facilitate Compton scattering and coherent radiation generation experiments.

"Femtosecond mode"

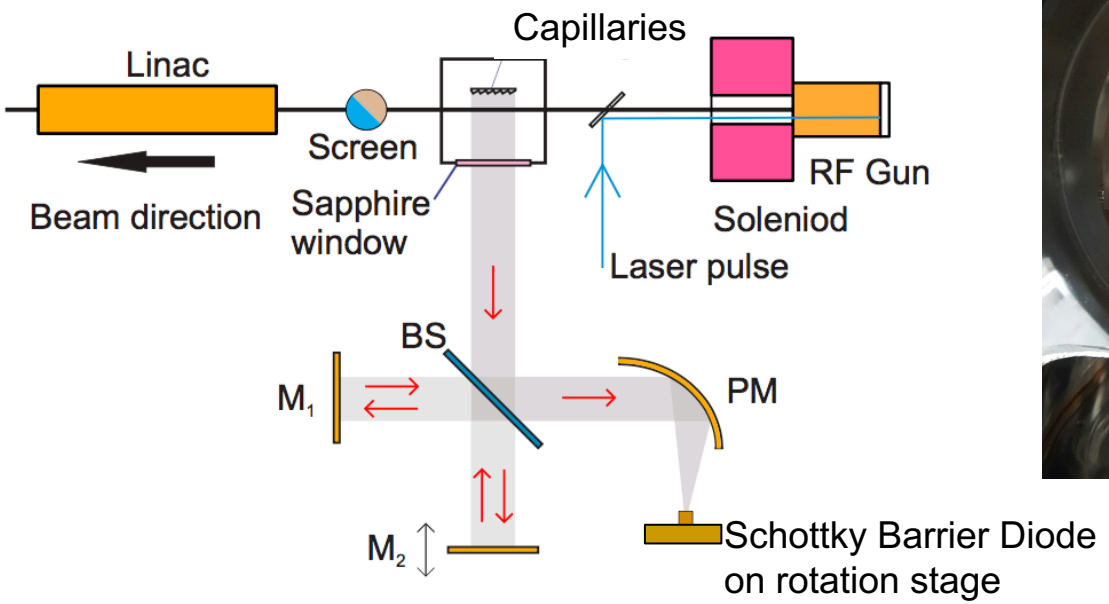
- Ti:Sa laser
- e-bunch RMS length ~100fs
- e-bunch charge < 100pC
- Single bunch train, Micro-bunching 4
- Typical Rep. rate 3.13 Hz
- Experiments: THz program

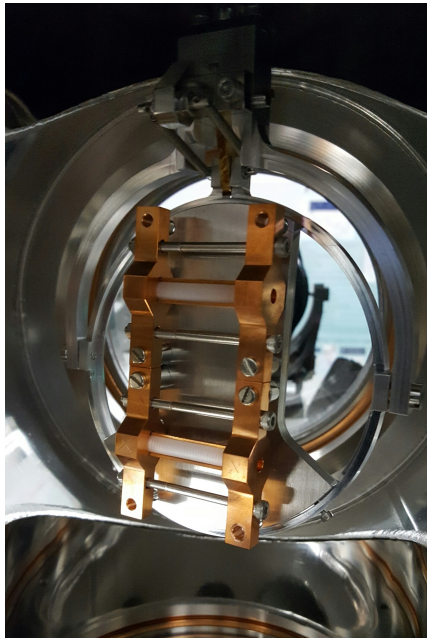
"Picosecond mode"

- Q-switch Nd:YAG laser
- e-bunch RMS length ~10ps
- e-bunch charge < 0.5 nC
- Multi-bunch train 2- few 10^3
- Max Rep. rate 12.5 Hz
- Experiments: Compton, CDR

Spectral measurements of Cherenkov Smith – Purcell Radiation

Experimental setup:





Beam parameters:

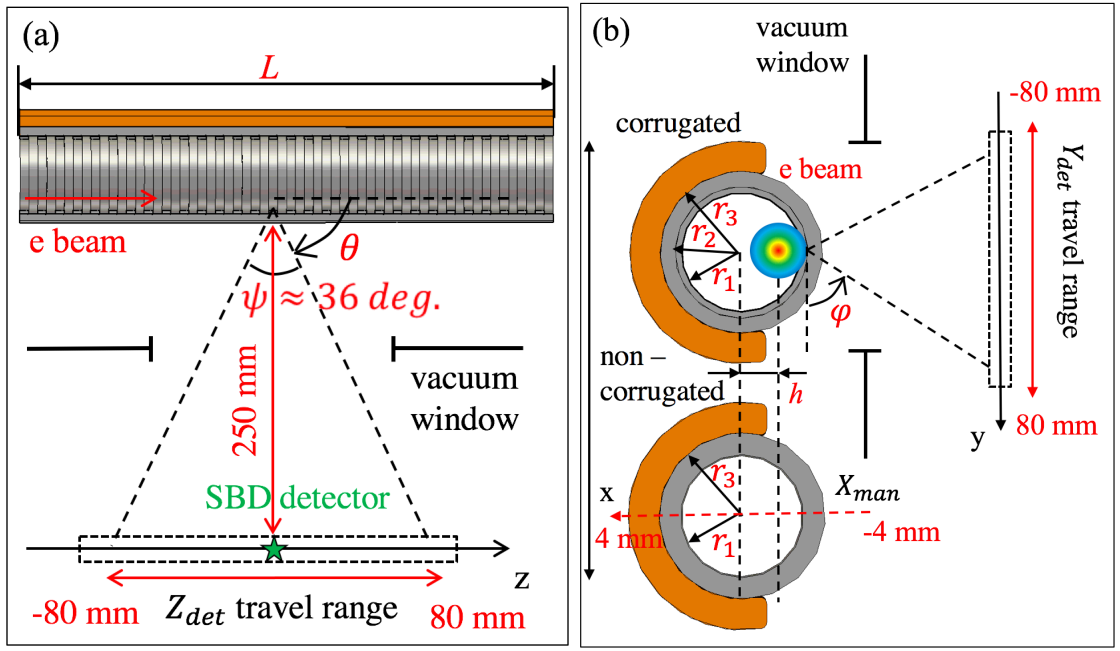
Parameter	Value
Bunch charge	~40 pC
Bunch length (sigma)	~0.7 ps
Bunch transverse size	~ 300 x 300 μm

Capillary parameters:

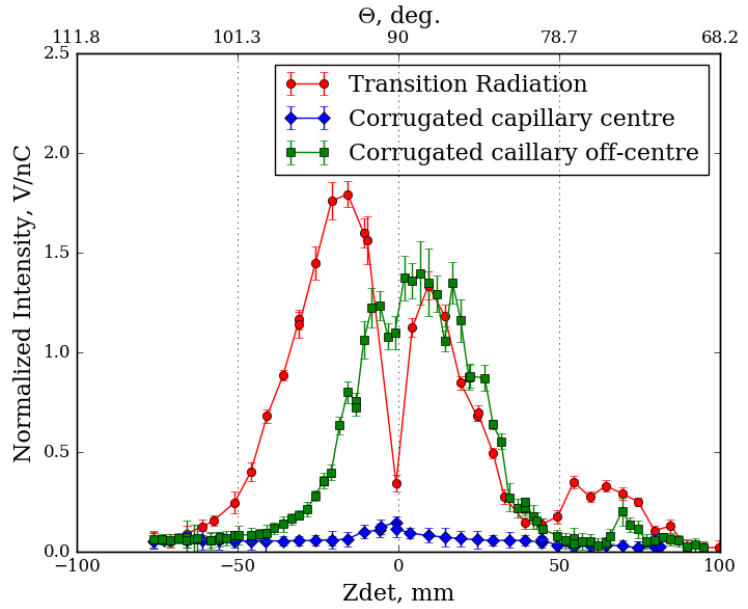
Parameter	Value
Corrugation period	1 mm
Bunch length (sigma)	~0.7 ps
Bunch transverse size	~ 300 x 300 μm

Earlier experiment (spatial distribution of ChSPR)

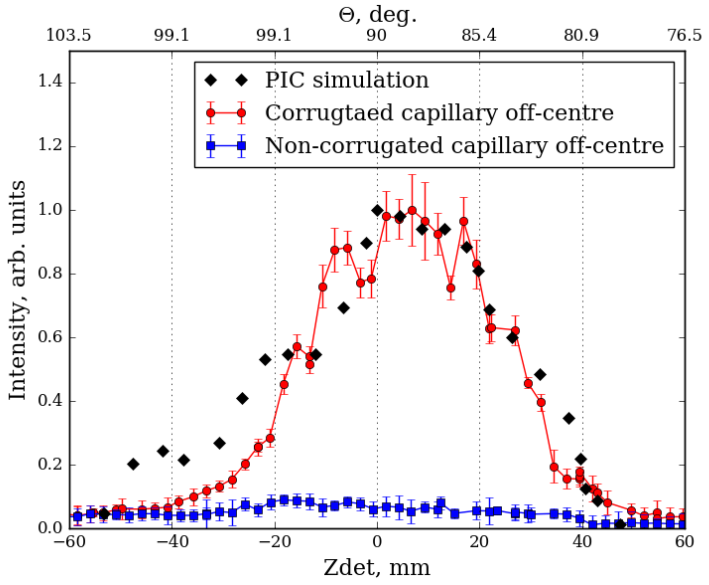
Experimental setup:



Crosscheck with Transition Radiation:

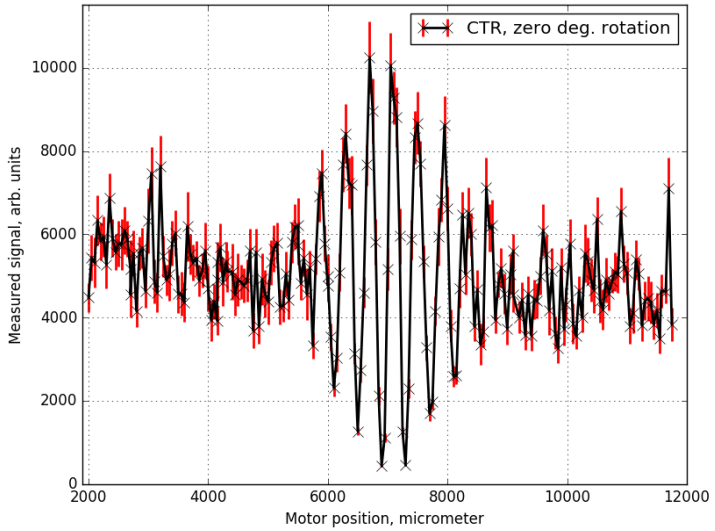


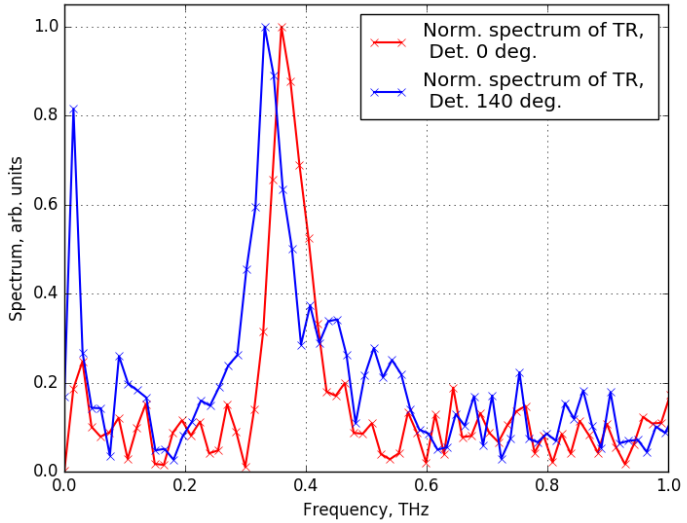
Corrugated vs Non-Corrugated:



*K. Lekomtsev et al., Sub-THz radiation from dielectric capillaries with reflectors, NIMB 402, 148 (2017).

Spectral response of SBD detector (Transition Radiation)

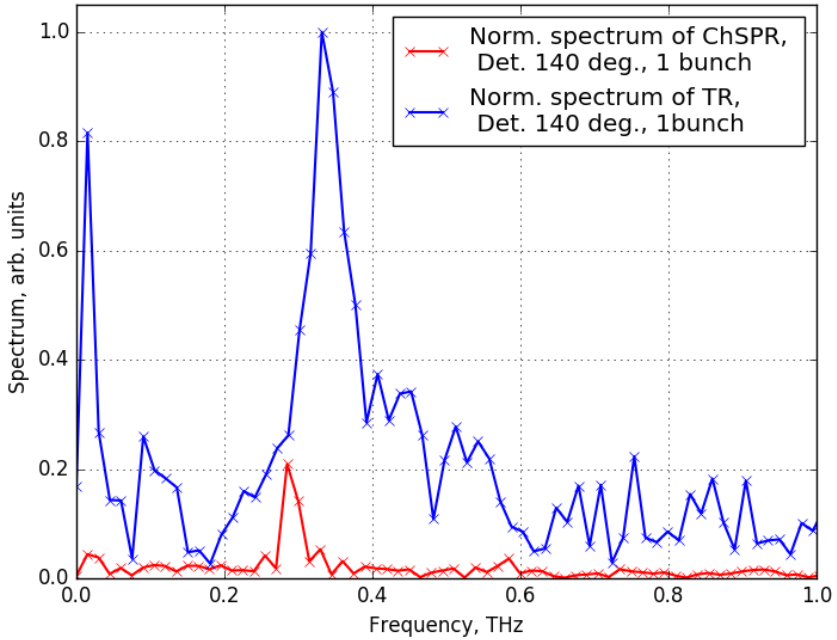




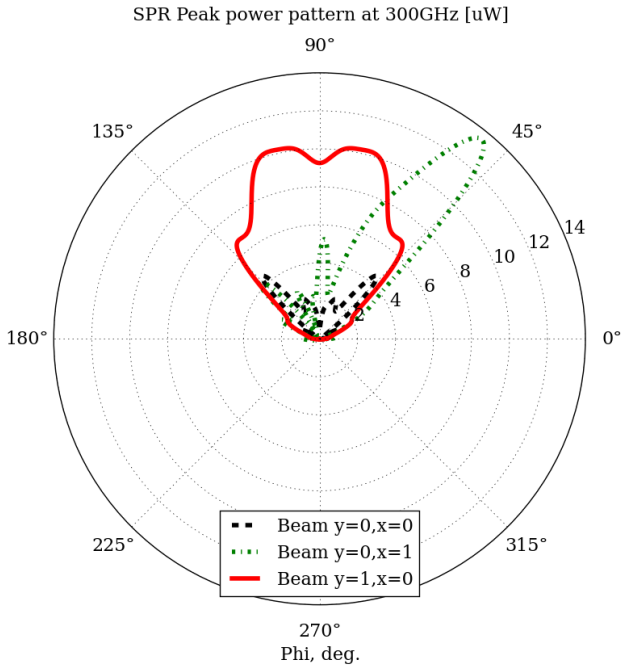
Spectral intensity calculated as:

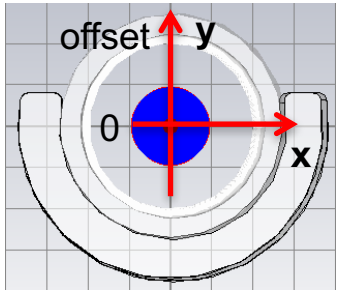
$$S(f) = \frac{1}{\pi}\int_{-\infty}^{\infty}[I(x) - I(\infty)]exp\left(-i\frac{2\pi f}{c}x\right)dx$$

Current stability at 0.3%



Spectral measurements (beam transverse offset)

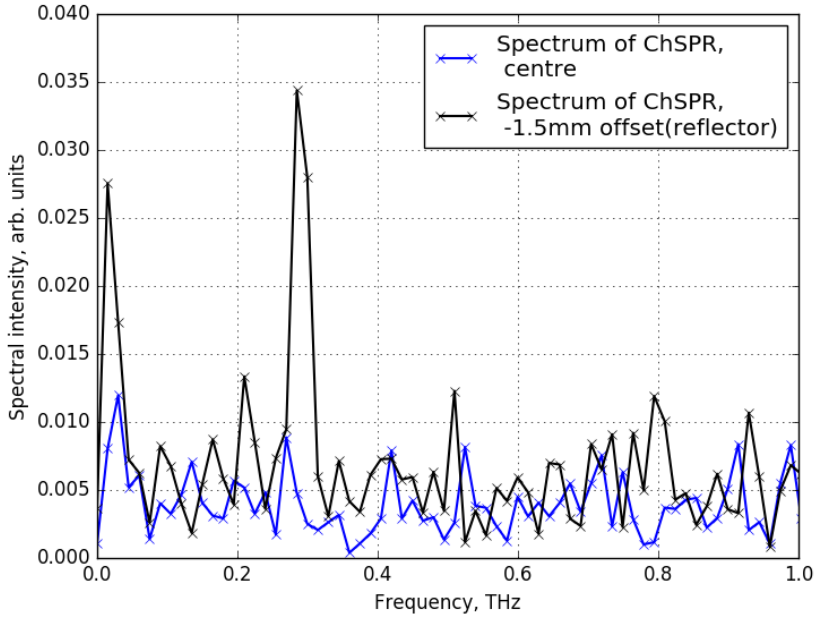


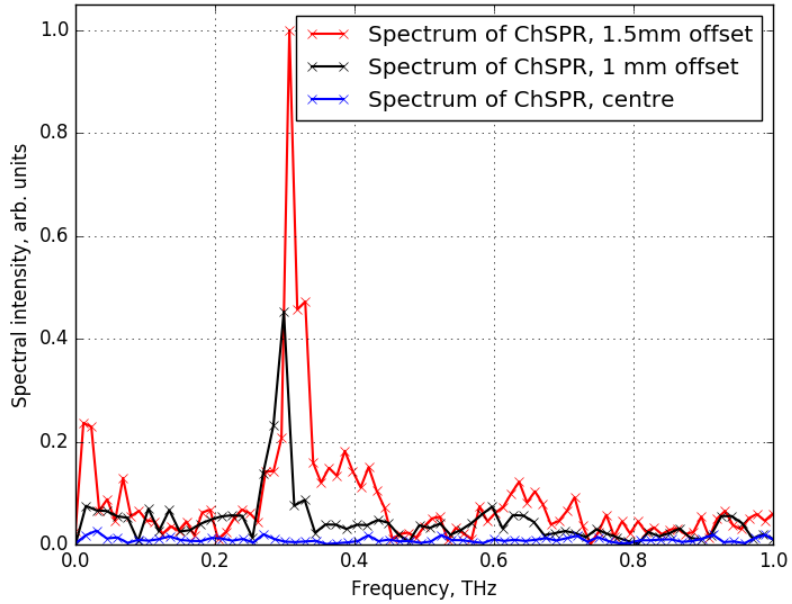


In zy plane each transverse off-set has its unique spectral intensity.

Axial beam propagation –> “Flat” spectrum.
Any beam off-set from axis –> Spectrum with the peak at ≈ 300 GHz.

Spectra for different transverse beam offsets in corrugated capillary:

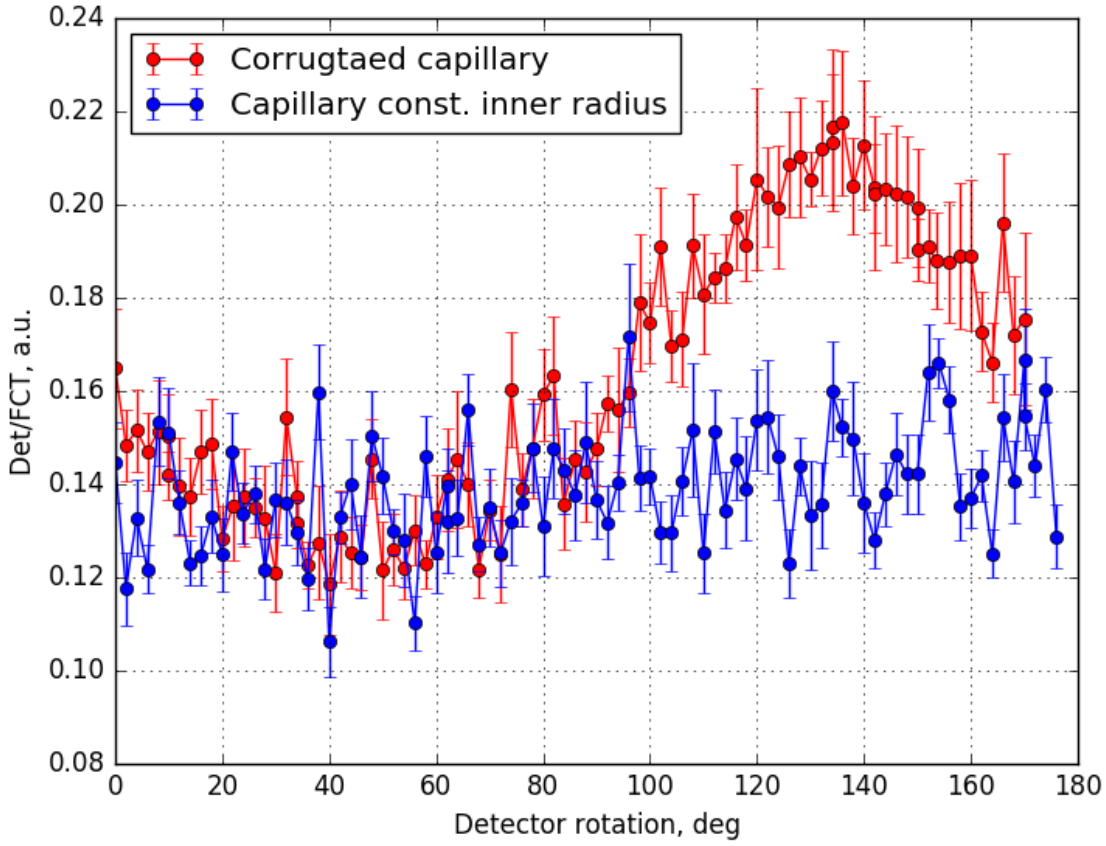




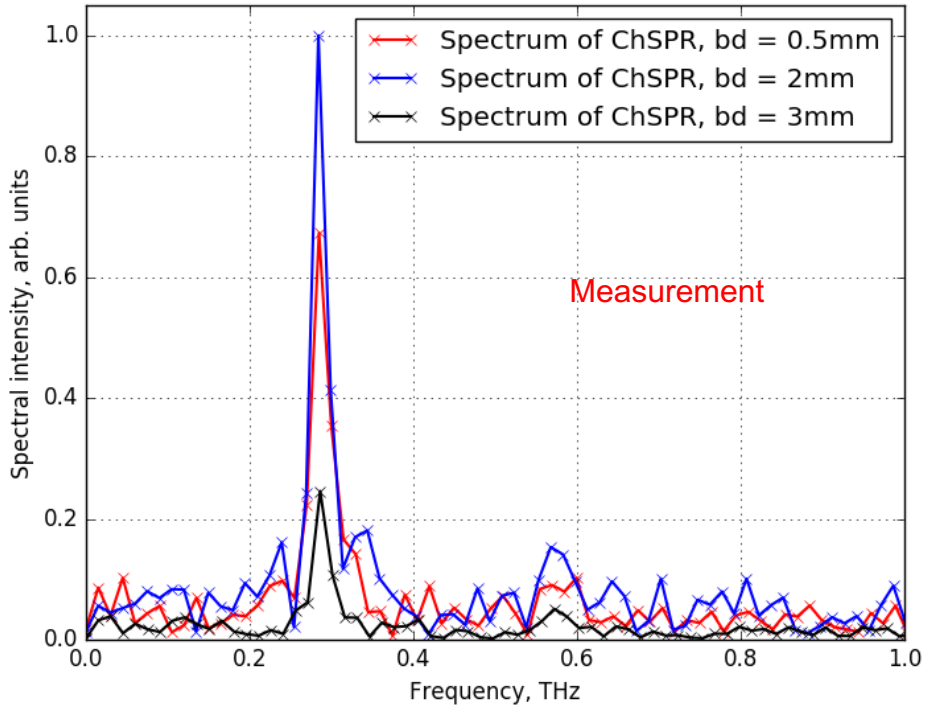
Polarization measurements (ChSPR)

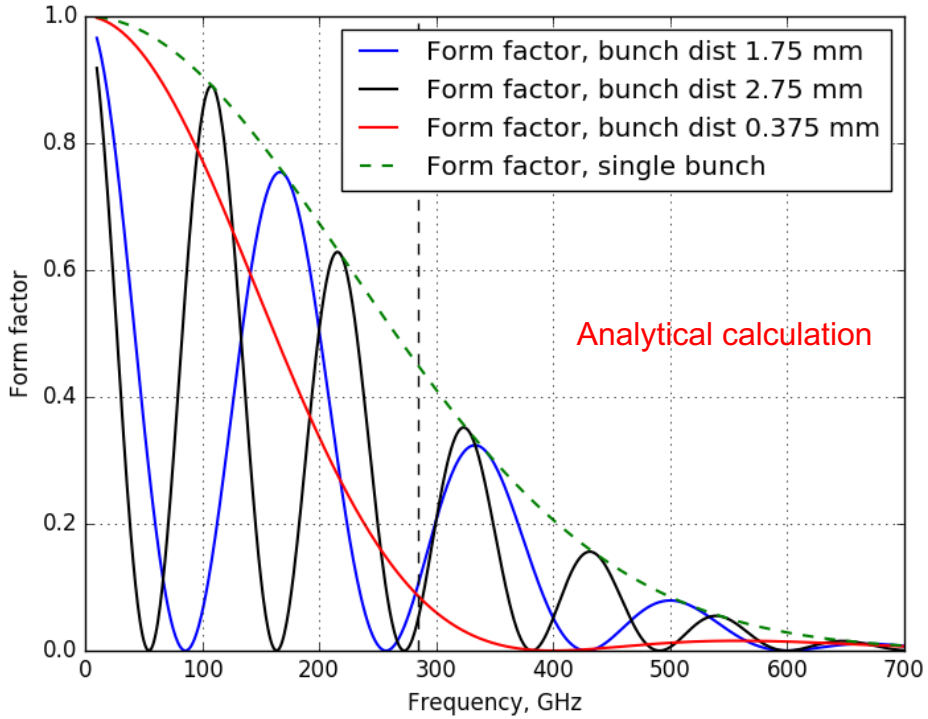
Corrugated capillary vs Capillary with constant inner radius:

The graph shows that the ChSPR emitted from the corrugated capillary is polarized and the maximum of the detected radiation is at ≈140 deg. detector rotation.



Spectral measurements (2 bunches)





Estimate of bunch distance using laser path difference, mm	Estimate of bunch distance based on form factor, mm
0.5	0.375
2	1.75
3	2.75

Coherent radiation spectrum:

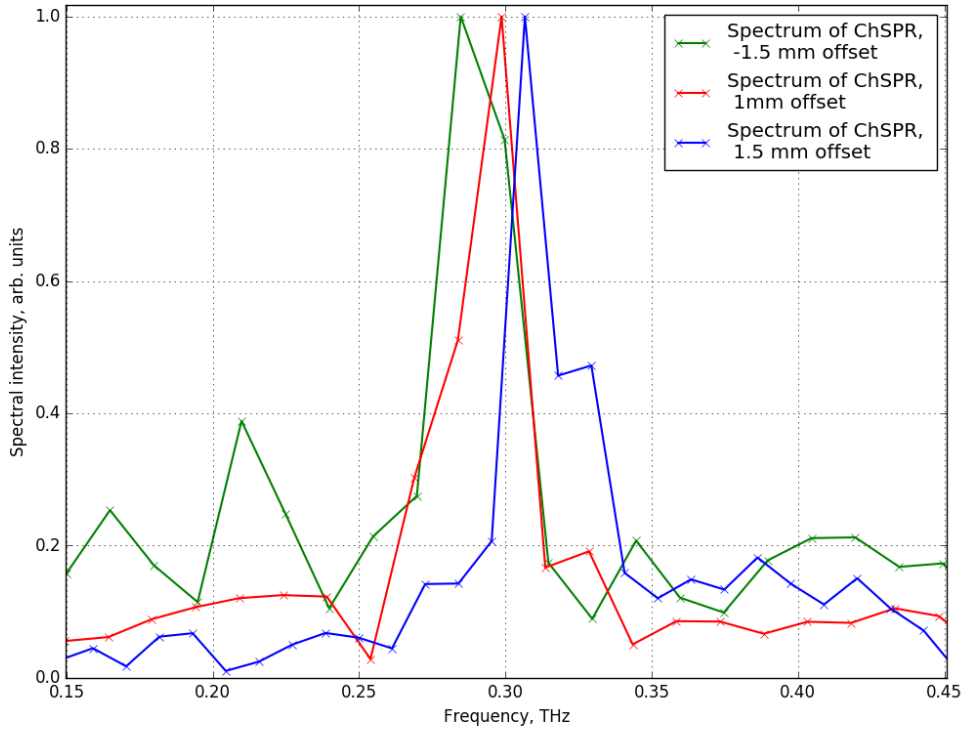
$$S_{total}(\omega) \cong S_{single\_particle}(\omega) * N^2_{particles} * F(\omega).$$

Form-factor of a double Gaussian (2 bunches):

$$F(\omega) = \frac{1}{4}\left(exp\left[-\frac{\sigma_1^2\omega^2}{c^2}\right] + exp\left[-\frac{\sigma_2^2\omega^2}{c^2}\right] + 2exp\left[-\frac{\omega^2}{c^2}\frac{(\sigma_1^2+\sigma_2^2)}{2}\right] cos\left(\frac{\omega}{c} * bunch\_dist\right)\right).$$

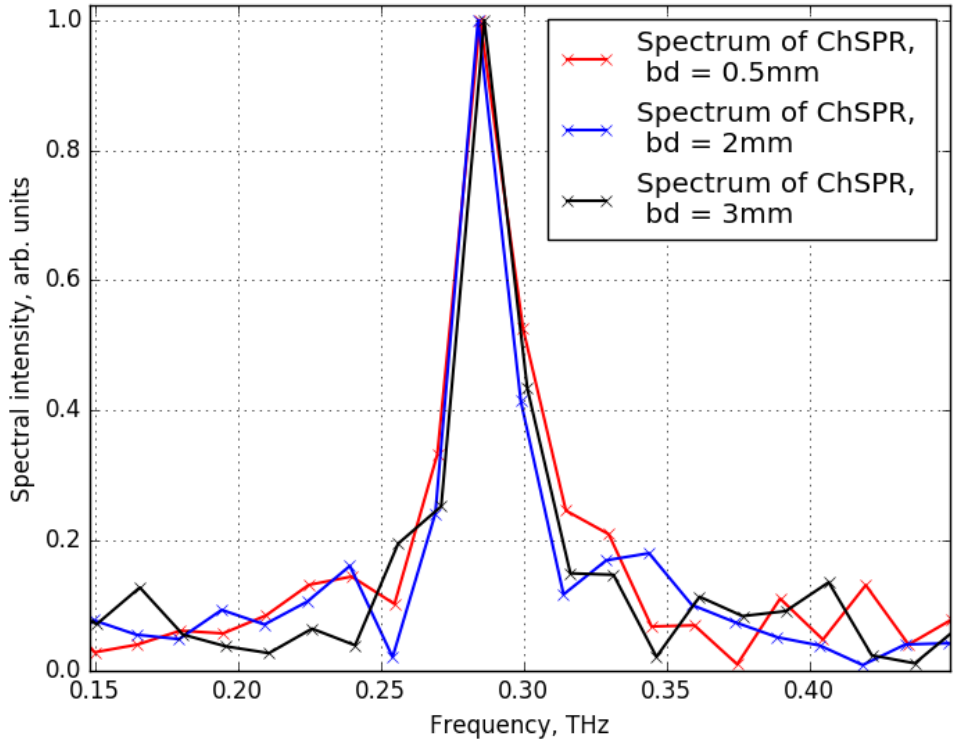
Spectral measurements

1 bunch, beam transverse offset: -1.5; 1; 1.5mm



vs

2 bunches, bunch separation: ≈ 0.5; 2; 3 mm



Spectrum shift observed for different beam off-sets is yet to be understood using simulations.

Conclusions

1. Spectral measurements of ChSPR were performed for single and two-bunch beams.
2. Modulation of the power spectrum intensity was measured for different transverse off-sets of the single bunch beam in the capillary.
    - The ChSPR radiation intensity change as well its spectrum modulation for different beam offsets can be used for beam position monitoring or as a beam position feedback system (in the considered geometry only in zy plane) in **conventional RF** as well as **future dielectric based accelerators**.
3. Modulation of the ChSPR spectrum by the two-bunch beam was measured and bunch separation was reconstructed by matching analytical form factor modulation to the measured ChSPR spectrum modulation.
    - This technique can be used as a second order correction or used directly to monitor the distance between bunches.