THz@CLEAR:

Source and diagnostics for electron acceleration

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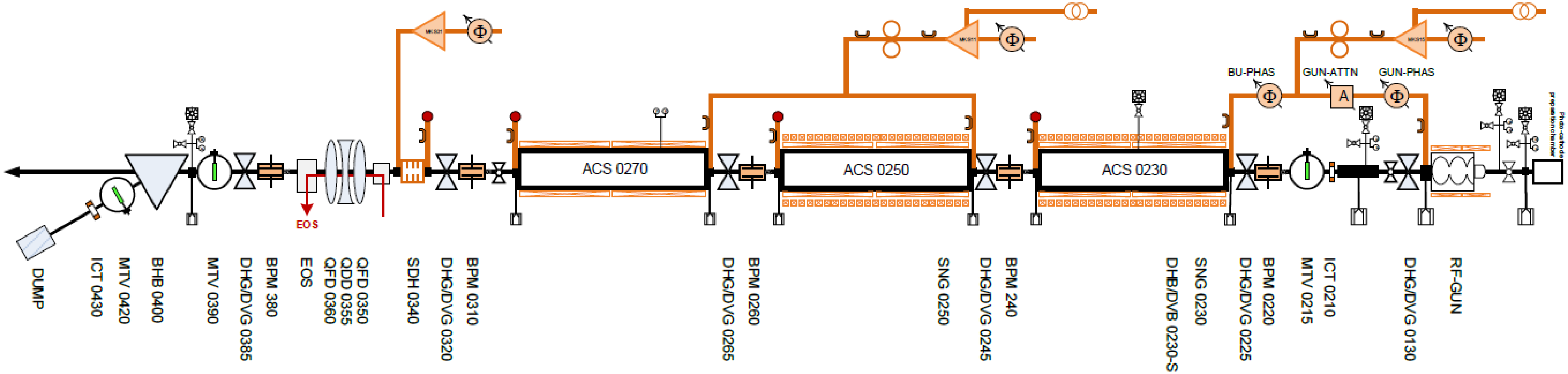
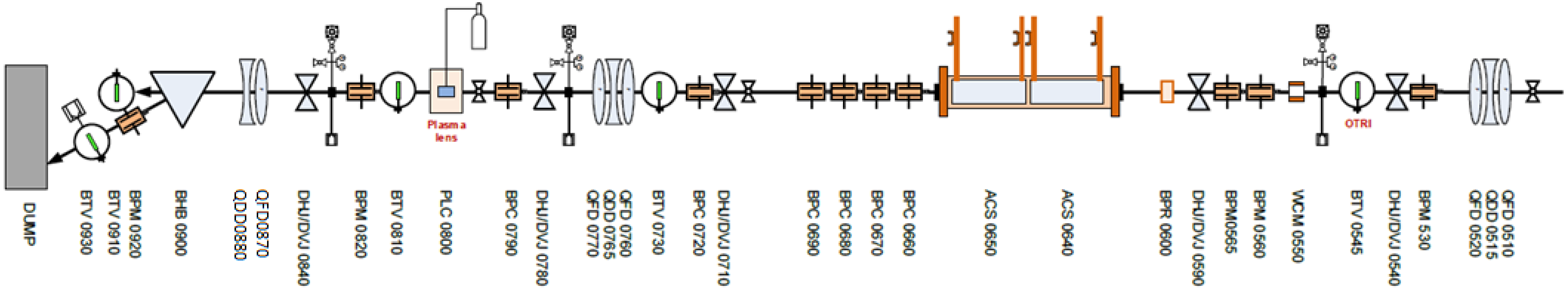
Outline

- Presentation of CLEAR
- The current developments at CLEAR for THz generation, first results
- Conclusions and possible longer-term applications of THz radiation at CLEAR

Present layout of CLEAR (2018)

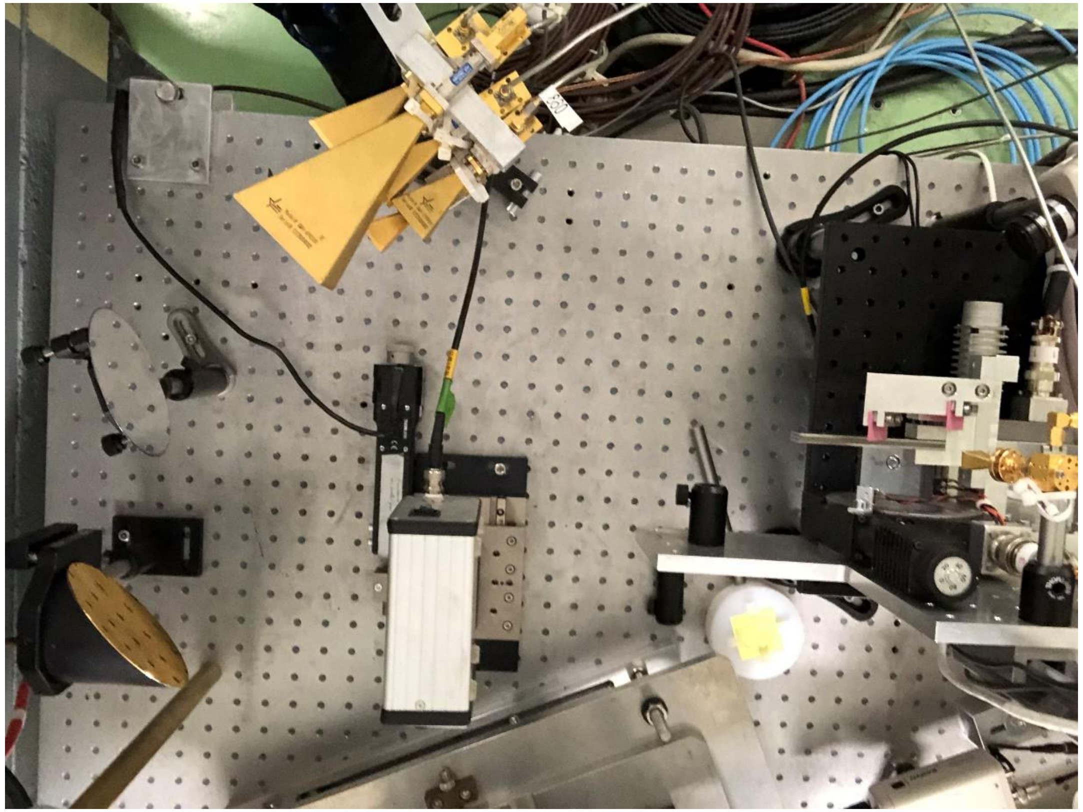




CLEAR performances

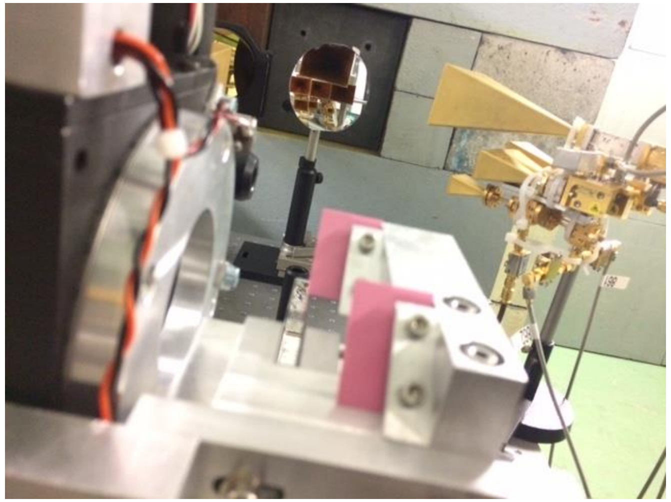
Beam parameters	Range	Comments
Energy	60 – 220 MeV	More flexible with 2 klystrons. > 220 MeV with pulse compression.
Energy Spread	< 1 MeV (FWHM)	
Bunch Charge	1 pC – 200 pC	Photocathode changed but limited laser power. Goal: 0.6 nC.
Bunch Length	0.2 ps – 10 ps	0.1 ps with velocity bunching
Normalized emittances	3 μm to 30 μm	Bunch charge dependent
Repetition rate	0.8 to 5 Hz	25 Hz with klystrons and laser upgrade
Number of micro-bunches in train	1 to >150	Single bunch capability assessed
Micro-bunch spacing	1.5 GHz (Laser)	3.0 GHz: Dark current

In air test-stand for THz radiation tests

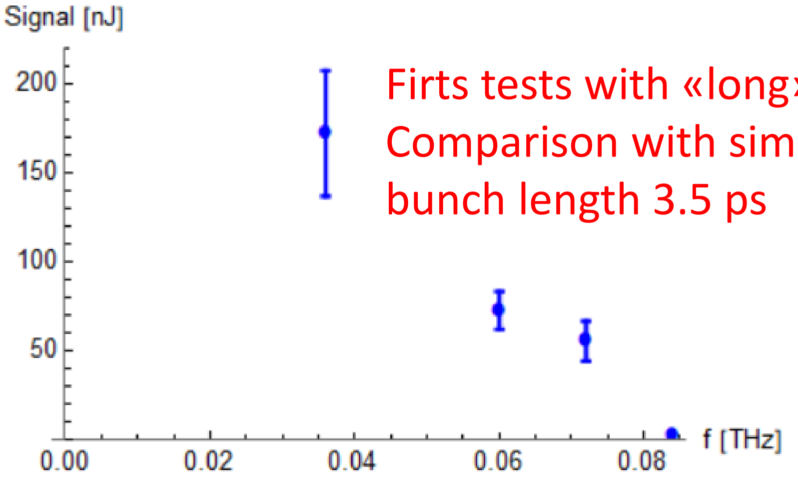


- Bottom-left: Pyroelectric detector for measuring radiation within 0.1-30 THz
- Top-left: Coherent transition radiation detection with Schottky diodes 30-300 GHz
- Bottom-right: Smith Purcell grating for studies in the range 0.1-1 THz

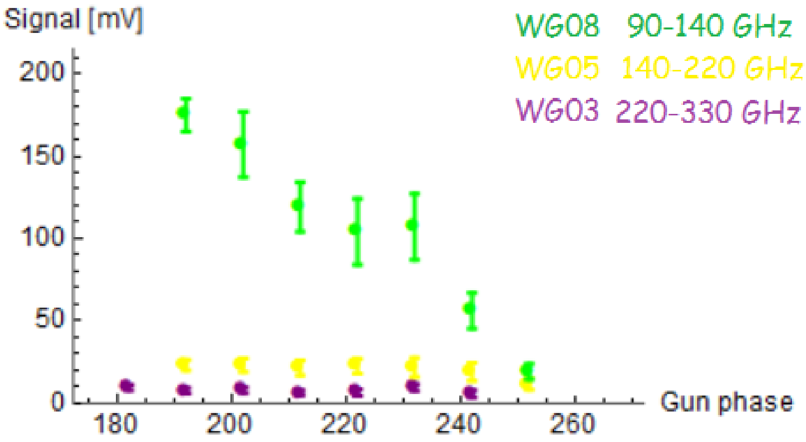
The CLEAR experiment of (sub-)THz generation with CTR



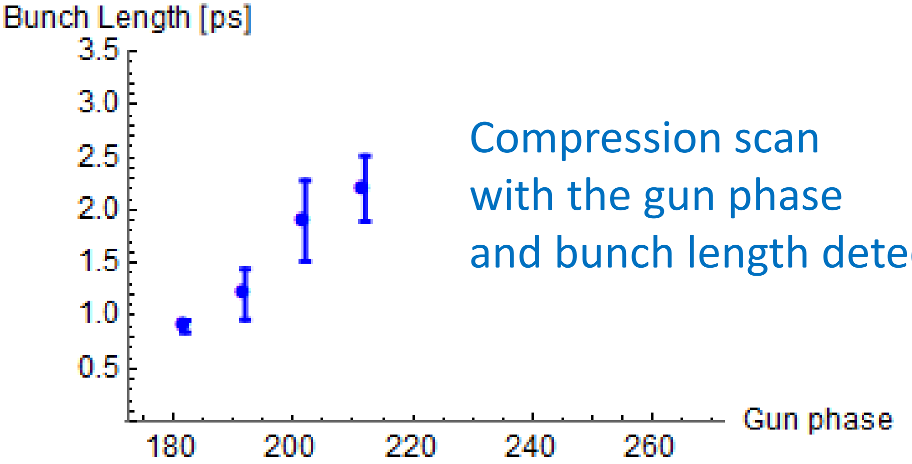
Complete set of Schottky Diodes from 30 to 300 GHz



Firts tests with «long» bunch. Comparison with simulations gives bunch length 3.5 ps



Signature of the bunch compression



Compression scan with the gun phase and bunch length detection

Techniques for longitudinal diagnostics with CTR

One way is to completely characterize the CTR spectrum, retrieving then from there the bunch form factor (eventually comparing with simulations)

A second way is to detect the CTR signal S at least with two detectors (angle of collection and photon energy must be different for different detectors), then taking the ratio between signals, comparing with the theory and finding the bunch length which minimizes the difference between theory and experiment:

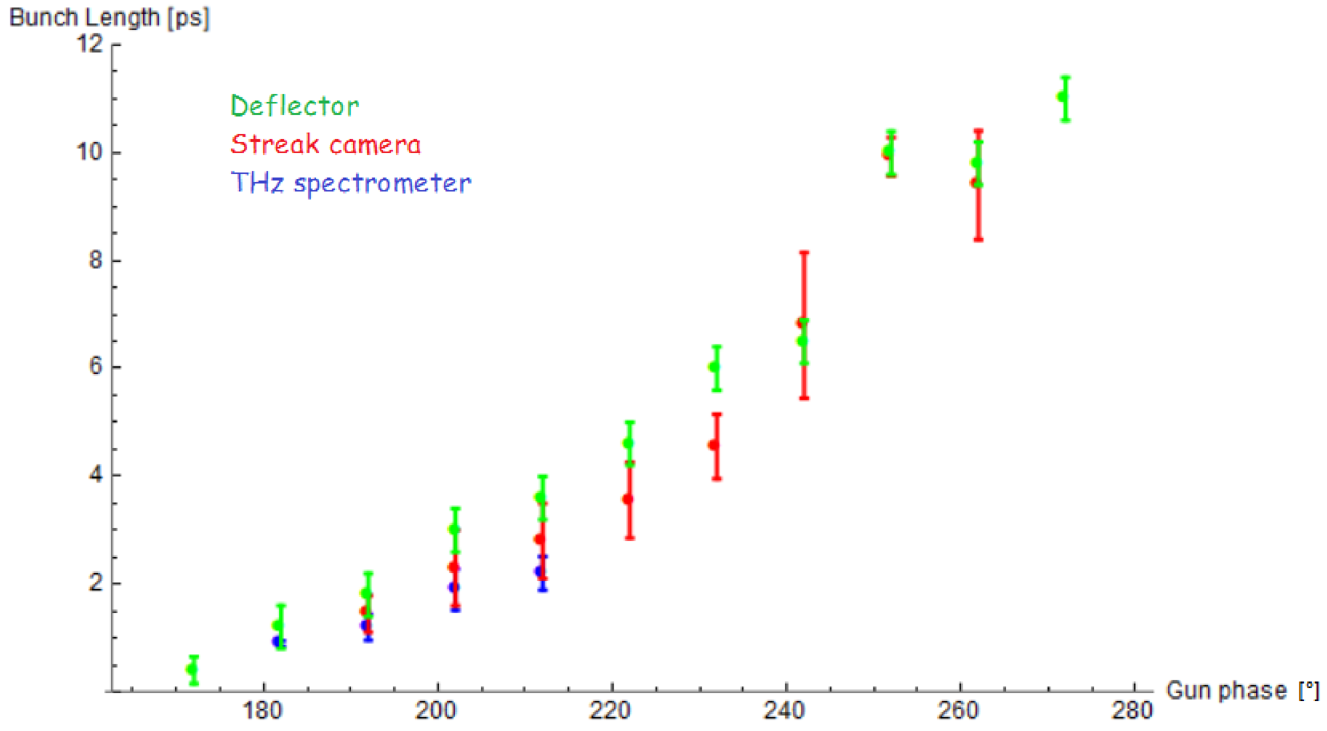
$$F(\omega_1^2-\omega_2^2,\sigma_\tau)\frac{\frac{dI_{sp}}{d\Omega d\omega}(\omega_1,\Omega_1)}{\frac{dI_{sp}}{d\Omega d\omega}(\omega_2,\Omega_2)}=\frac{S_1(\omega_1,\Omega_1)}{S_2(\omega_2,\Omega_2)}$$

Ratio between two signals

Theoretical expectation for the signal ratio due to a gaussian bunch

$$\sigma_\tau=\sqrt{\left|\frac{1}{\omega_1^2-\omega_2^2}\log\left\{\frac{\frac{dI_{sp}}{d\Omega d\omega}(\omega_2,\Omega_2)}{\frac{dI_{sp}}{d\Omega d\omega}(\omega_1,\Omega_1)}\frac{S_1(\omega_1,\Omega_1)}{S_2(\omega_2,\Omega_2)}\right\}\right|}$$

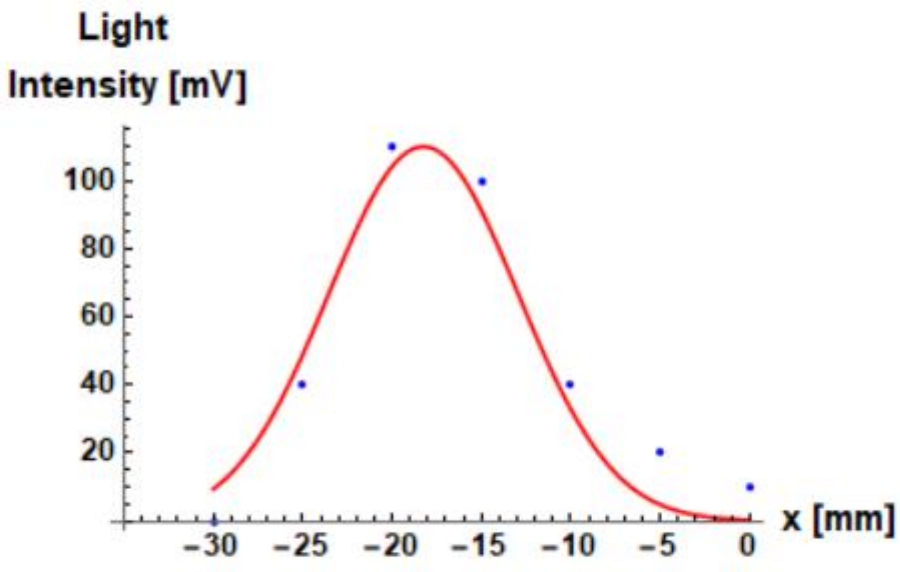
Full set of diagnostics for bunch length measurement



Comparative study among three different longitudinal diagnostic techniques:

1) Deflector cavity
2) OTR streak camera measurements
3) THz spectrometry

First tests with the pyroelectric detector



SPECIFICATIONS

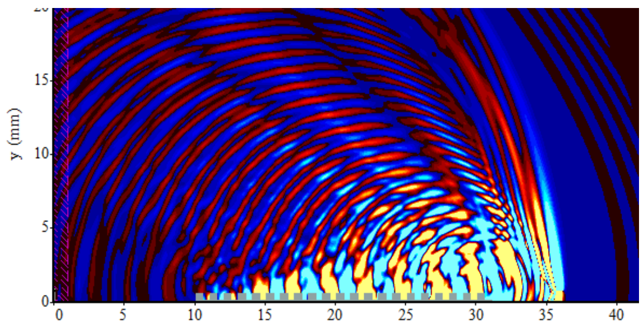
	QS5-THZ-BL
VOLTAGE RESPONSIVITY	70 kV/W
EFFECTIVE APERTURE	5 mm Ø
PACKAGE	TO5
MEASUREMENT CAPABILITY	
Spectral Range [a]	
Frequency	0.1 - 30 THz
Wavelength	3000 - 10 μm
Max Power Density	50 mW/cm^2
Noise Equivalent Power	1.0 x 10^{-9} W/(Hz)^{½}
Detectivity [b]	4.10^{8} cm(Hz)^{½} /W
Voltage Responsivity [b]	70 kV/W
PHYSICAL CHARACTERISTICS	
Effective Aperture	5 mm Ø
Package	TO5
Sensor	Pyroelectric
Absorber	BL
Dimensions (Excluding Pins)	9.1Ø x 6.4D mm
Weight	45 g

Transverse scan for finding the THz focus, still not optimized on the longitudinal direction, therefore focus of 4 mm rms (roughly).

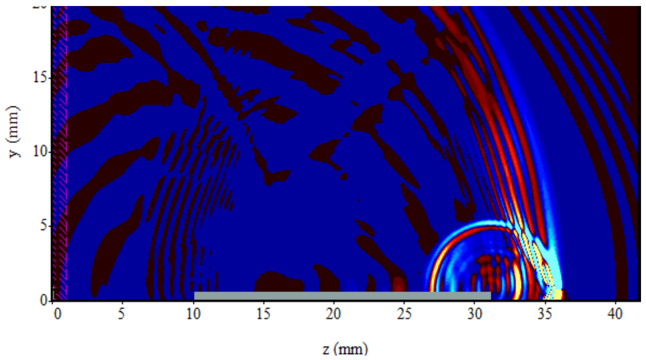
Measured signal consistent with uJ total energy collected from the radiatior as expected from simulations!

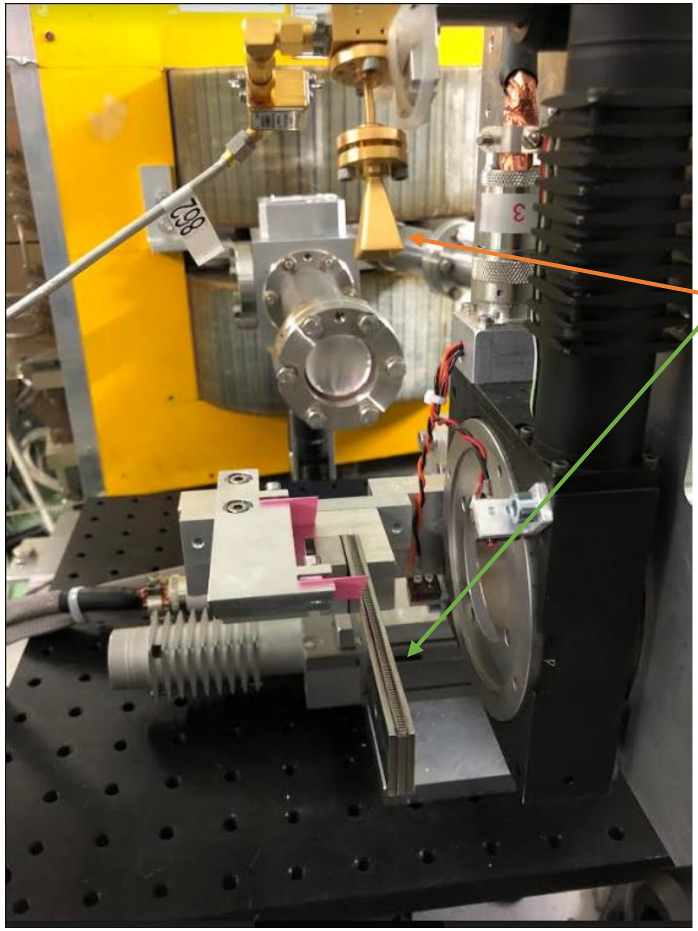
Next tests will be done with THz filters which are coming soon….

First tests with the Smith Purcell grating



t = 120 ps

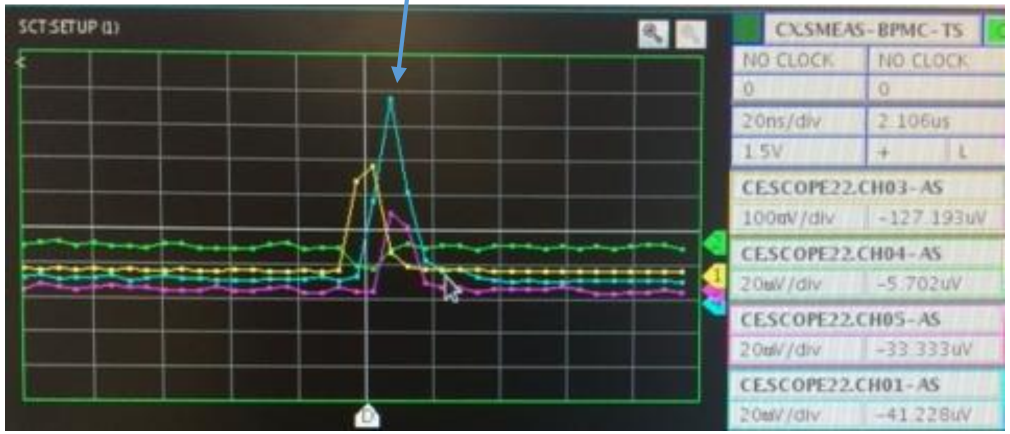




10 cm grating with
1 mm period installed
on a movable stage

Schottky diode WG05
installed at 107 ° from the plane of the
grating for detecting
the second harmonic at around 0.2 THz

Blue signal 150 mV, corresponding to
tens of uJ per pulse, but still under
investigation…



Thanks to Jacques Gardelle for
simulations with 3D MAGIC !

Conclusions and perspectives

Preliminary tests have been already done of sub-THz generation by CTR, still not managed to transport a compressed beam (few hundreds femto rms) with high charge down to the in air test-stand.

The possibility to use CTR for longitudinal diagnostics has been explored, but still further tests are needed with more complete setups, especially for short bunches below 1 ps rms

Applications of THz radiation @ CLEAR for electron acceleration/deflection should be the final goal, but still under discussion which way to go.

Before starting any THz-based experiment @ CLEAR, a complete characterization of the best possible CLEAR-based THz source is needed, which is the plan of next months.