

Non-destructive monitoring of electron beam micro-bunching periodicity.

INTRODUCTION

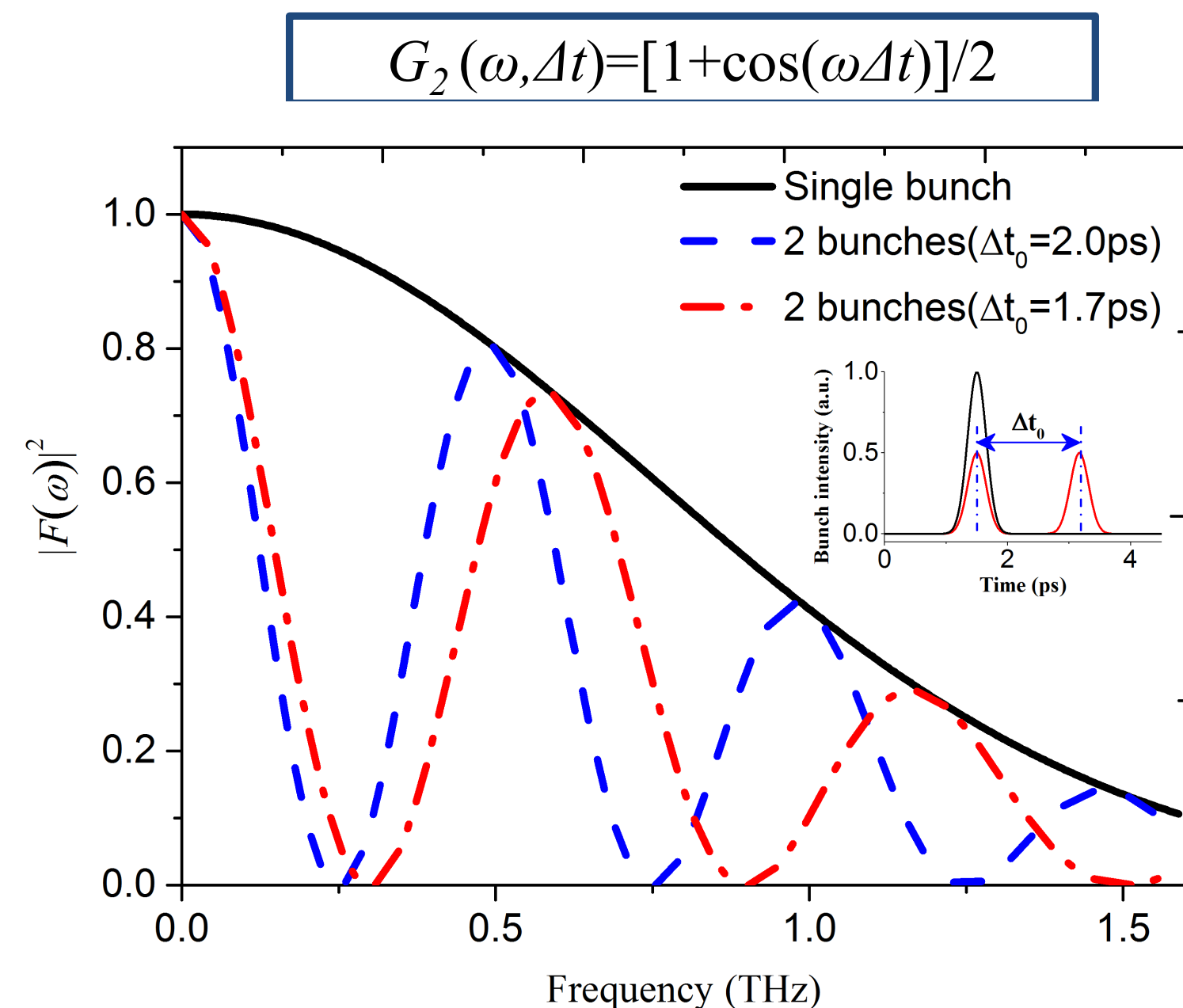
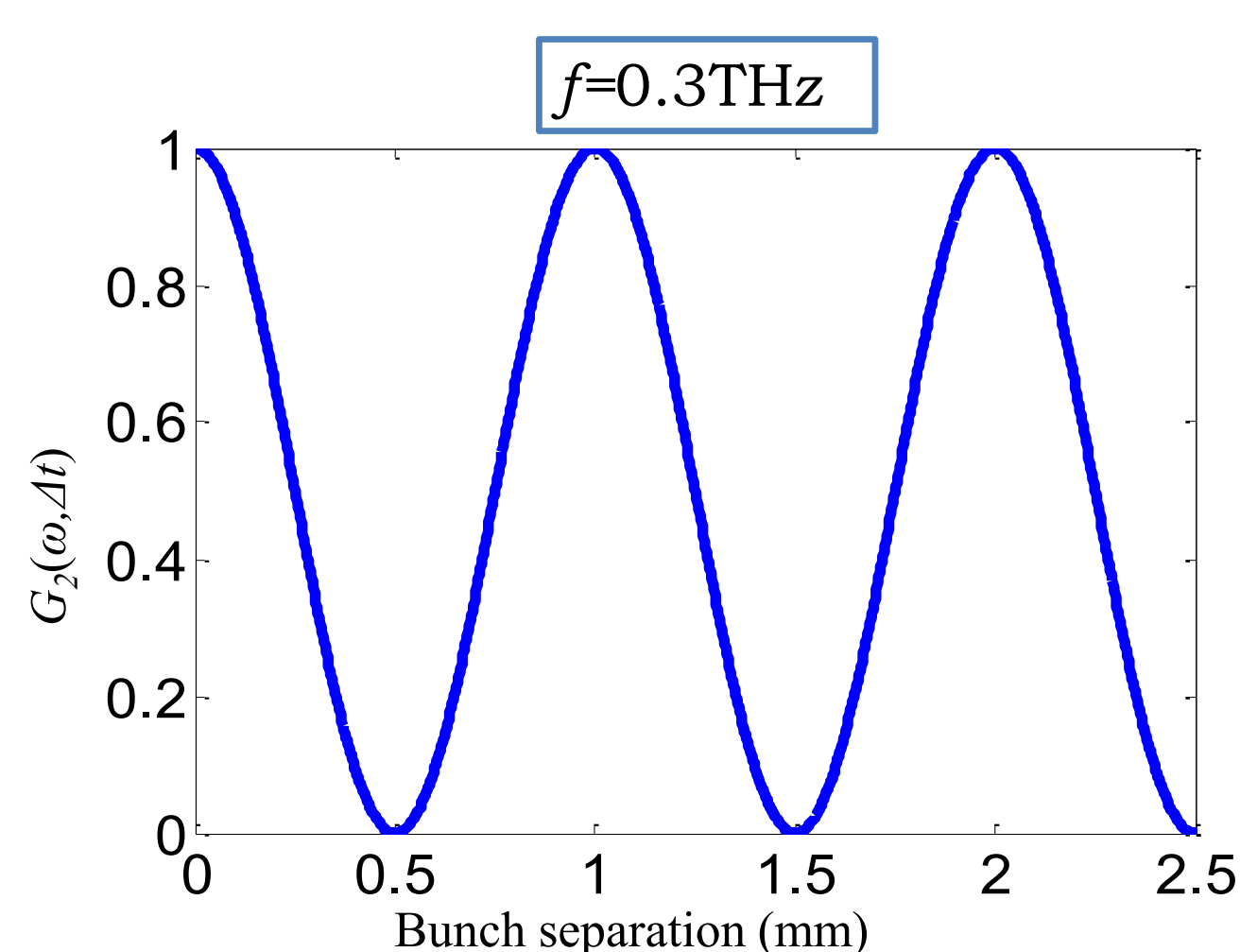
Electron beam microbunching can either occur naturally in high current accelerator facilities, or can be induced artificially for wide range of studies. Microbunching has applications in LINAC driven tunable sources of coherent radiation and wakefield acceleration. In all cases, an accurate, non-destructive monitoring of the beam microbunching is needed to validate theory, improve the accelerator and light source operations. It is still a challenge to monitor the beam microbunching non-destructively and we discuss the possibility of measuring the periodicity of the femtosecond microstructure of the beam without strong interference (i.e. in a non-destructive way) via analysis of the amplitude modulation of the coherent Smith-Purcell radiation (cSPr) signal generated by a partially or fully microbunched beam. The results of the numerical studies of the cSPr generated by the partially and fully microbunched beam and proof-of-principle experiments demonstrating the measurements of the distance between micro-bunches are presented.

BASIC PRINCIPLE

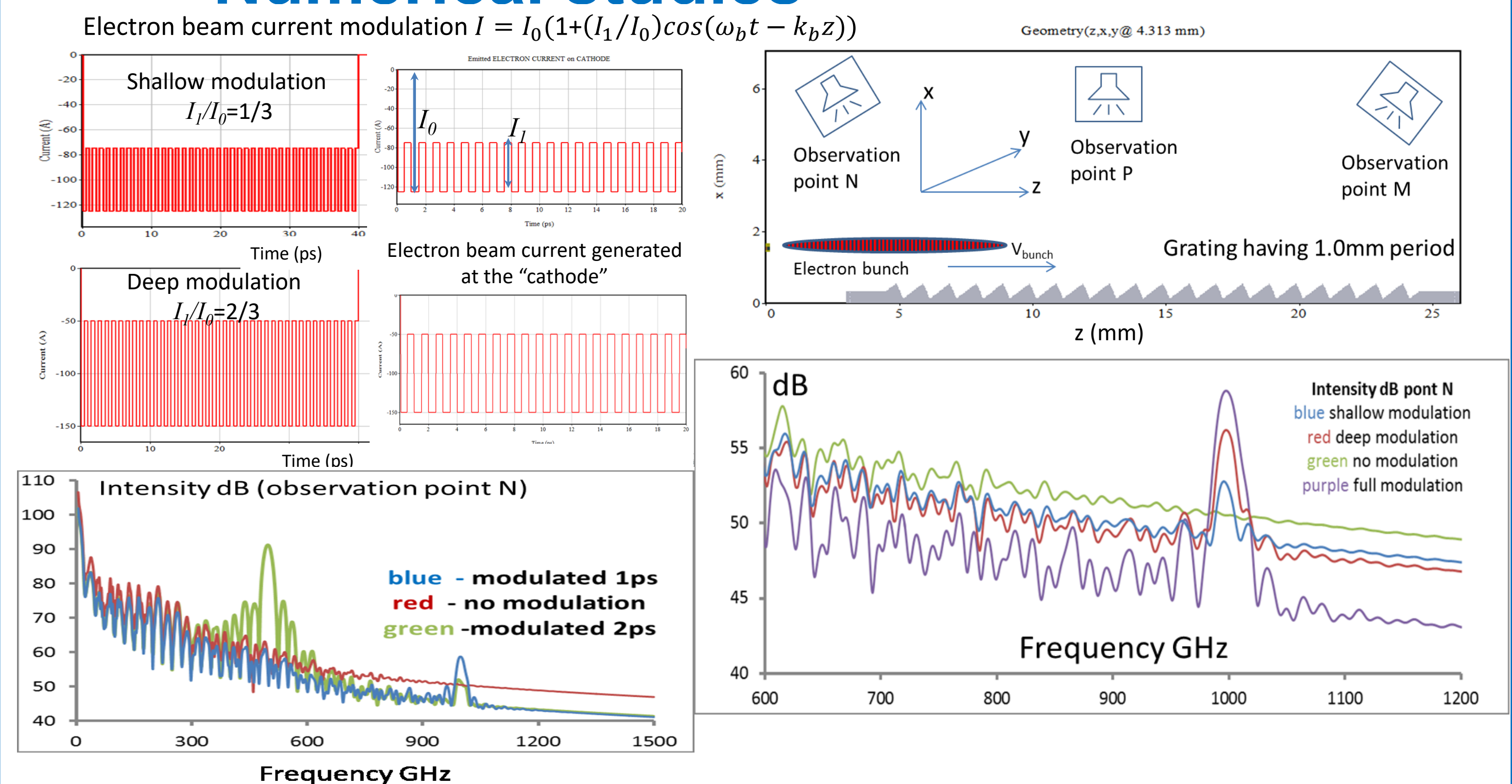
Radiation from M micro-bunches: $d^2I/d\Omega d\omega = (d^2I_0/d\Omega d\omega)[N_e + N_e(N_e - 1)|F(\omega)|^2]$

Form factor: $|F(\omega)|^2 = |F_1(\omega)|^2 G_M(\omega, \Delta t)$

$G_M(\omega, \Delta t) = 1/M^2 \sin^2(M\omega\Delta t/2) / \sin^2(\omega\Delta t/2)$

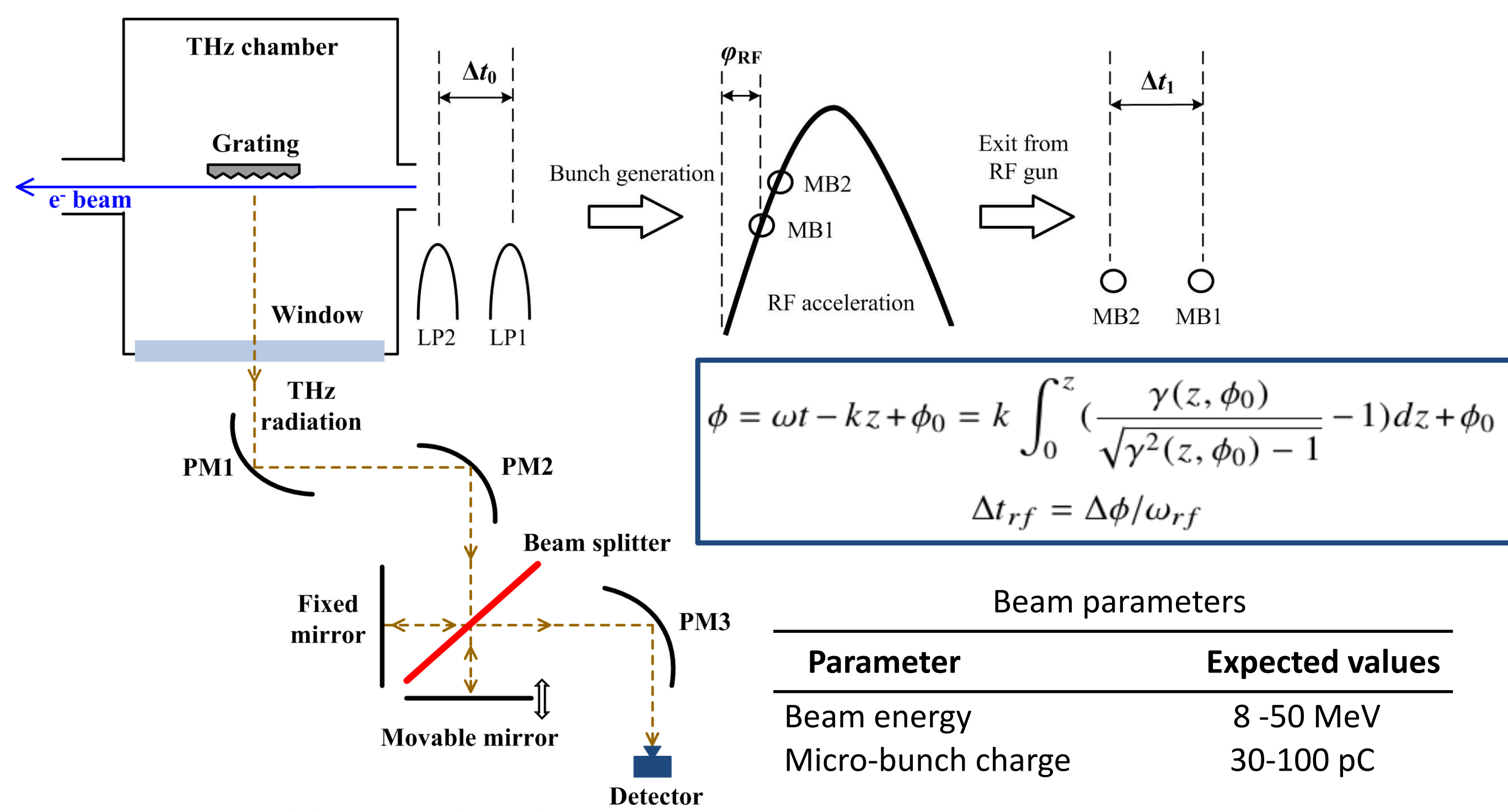


Numerical studies



RESULTS AND ANALYSIS

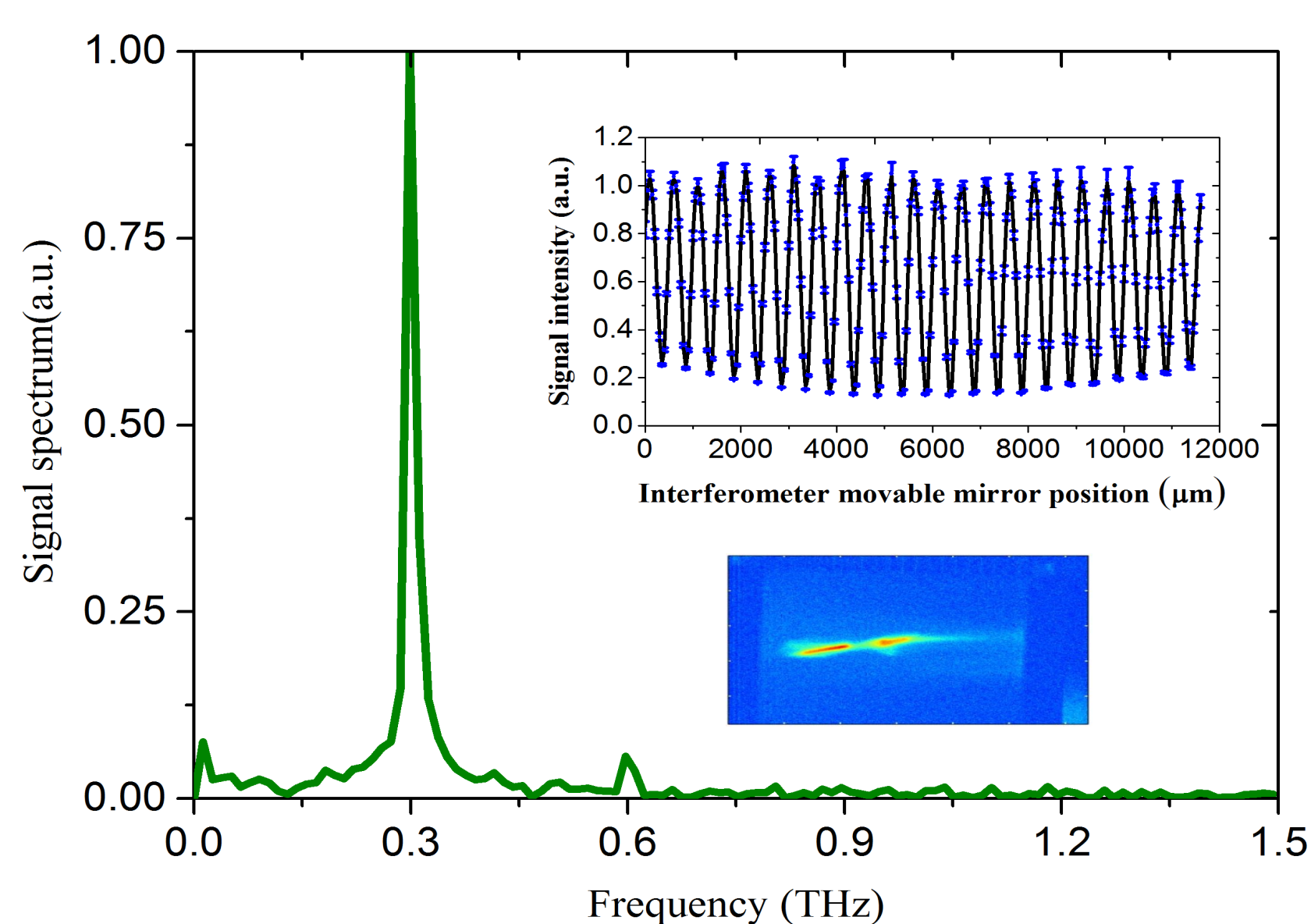
Experimental set up - schematic



Rev. of Sci. Instrum., 89(3), 035116 (2018)

- Bunch separation was varied by laser pulse separation ;
- Bunch separation is determined by laser pulse separation and RF gun phase;
- Radiation intensity from 2 bunches varies with bunch separation (as predicted).

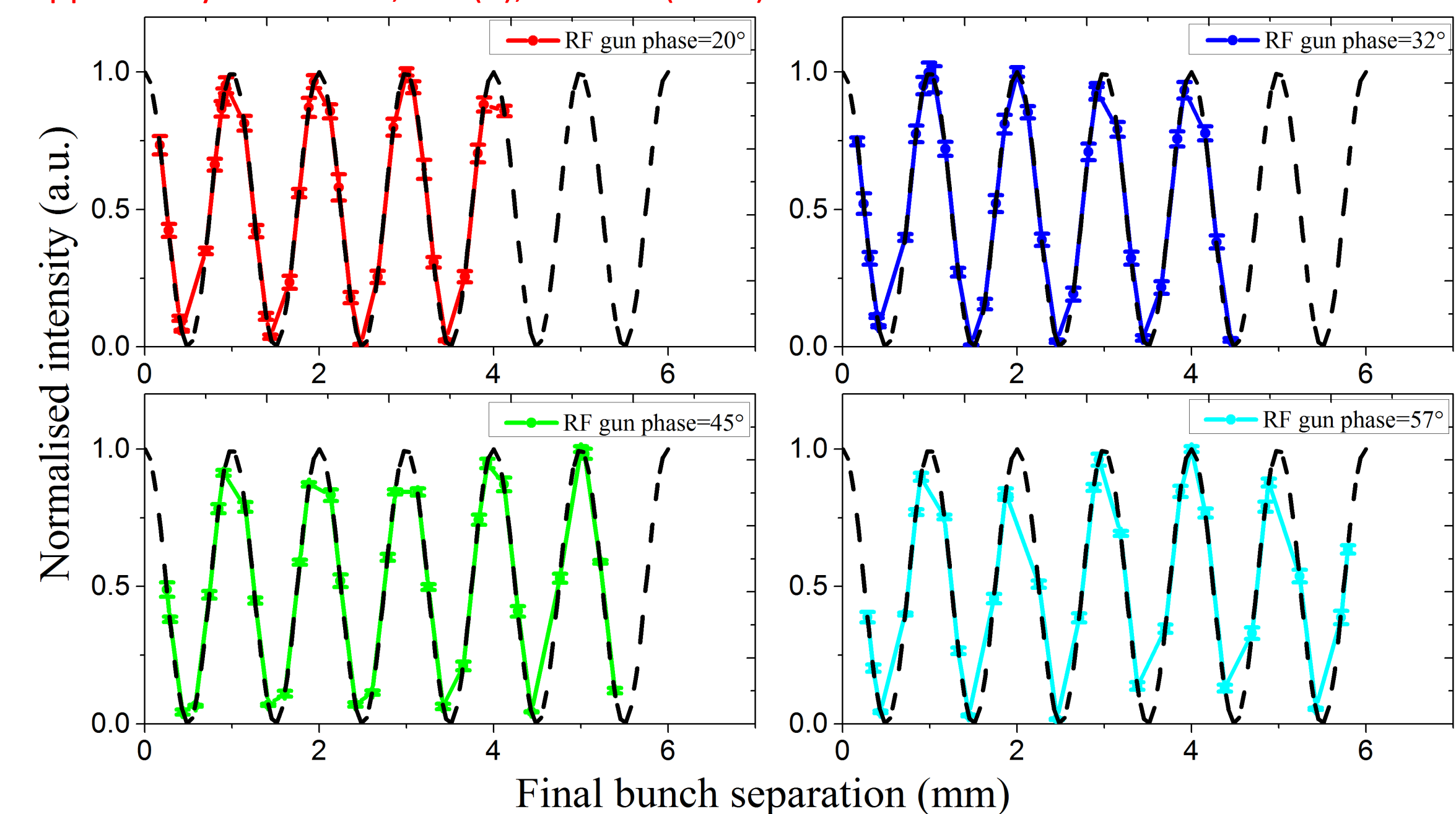
Confirmation of cSPr



- Two electron bunches are produced;
- Grating period 1mm, radiation at 90 degrees (0.3 THz, Smith-Purcell radiation).

Bunch separation reconstruction

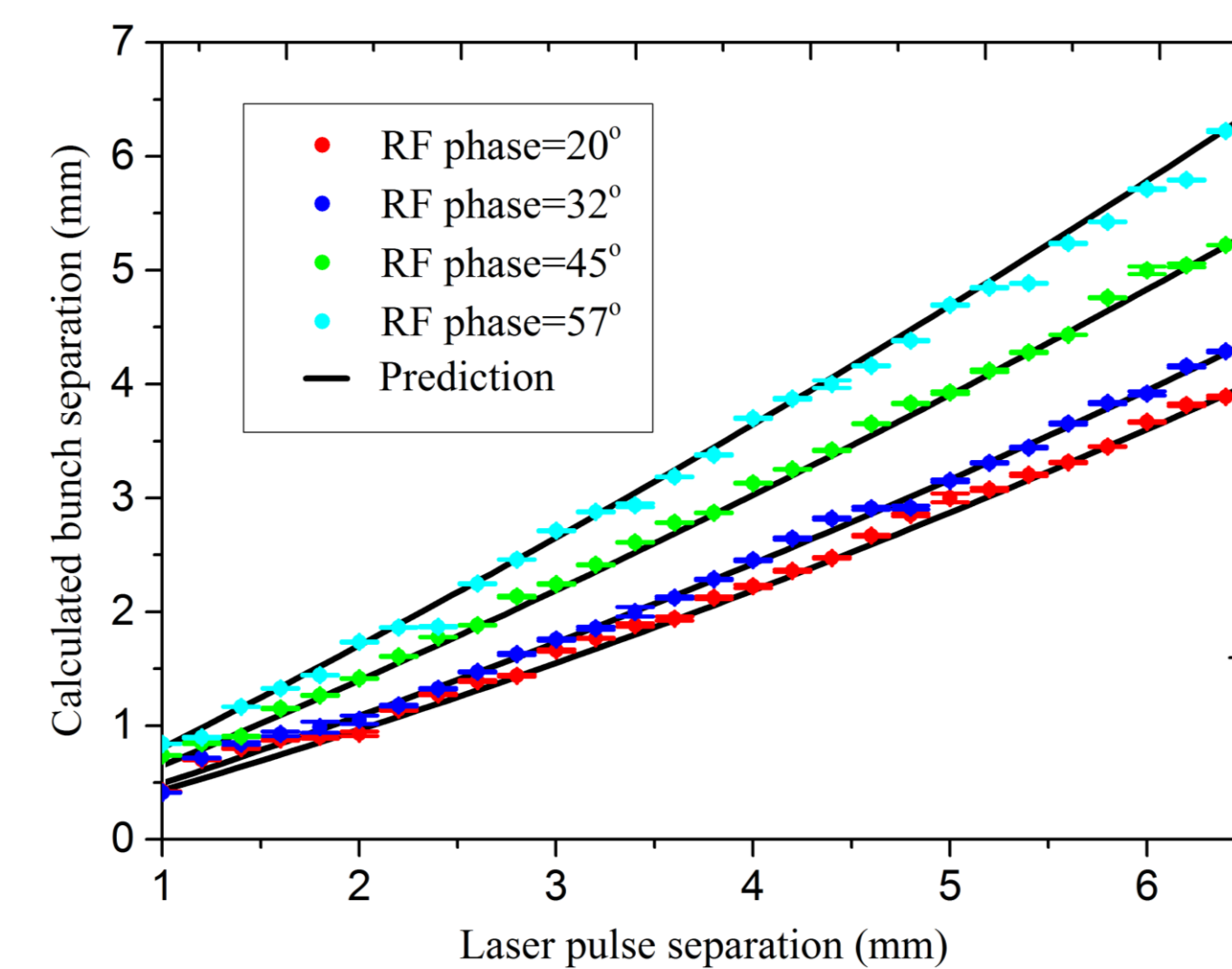
Applied Physics Letters, 111(4), 043505 (2017)



For each measurement, the corresponding real bunch separation Δt can be constructed by using $G_2(\omega, \Delta t) = [1 + \cos(\omega\Delta t)]/2$.

Comparison with analytical model

Good agreement with theoretical prediction.

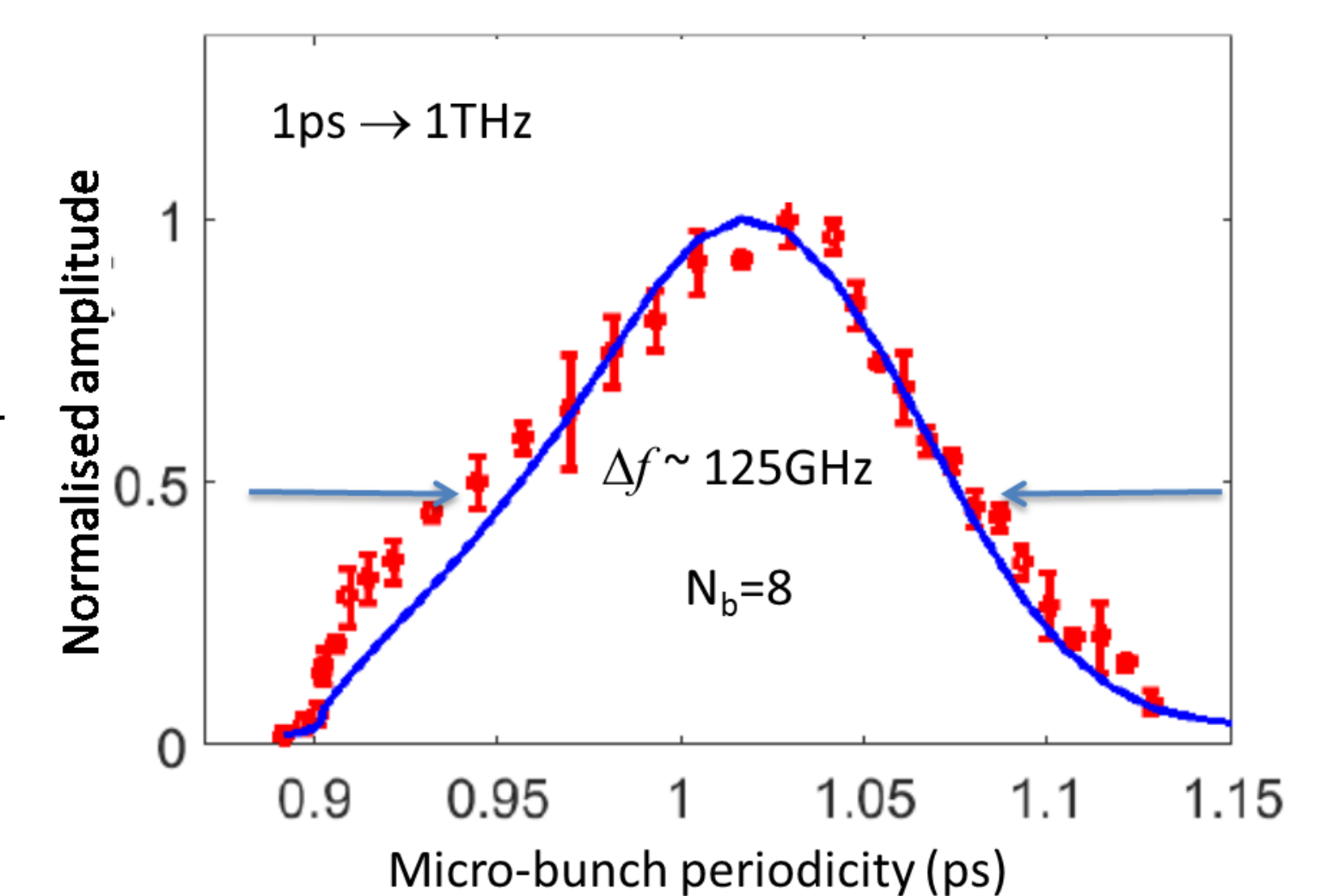


Dots with the error bars: reconstruction. Solid black lines: calculated using the re-evaluated bunch distance Δt_1 .

Applied Physics Letters, 111(4), 043505 (2017)

Variation of periodicity of microbunches

Applied Physics Letters, 112(5), 053501 (2018)



CONCLUSION

The monitoring of the microbunch periodicity and bunch separation was achieved by analysing the amplitude modulation of a monochromatic radiation signal from 2 and 8 bunches. There is a good agreement between reconstruction and theoretical prediction. The method can be used to provide feedback to control the sub-millimeter distance between the femtosecond long micro-bunches.