Hanbury Brown and Twiss interferometry at FEL FLASH.

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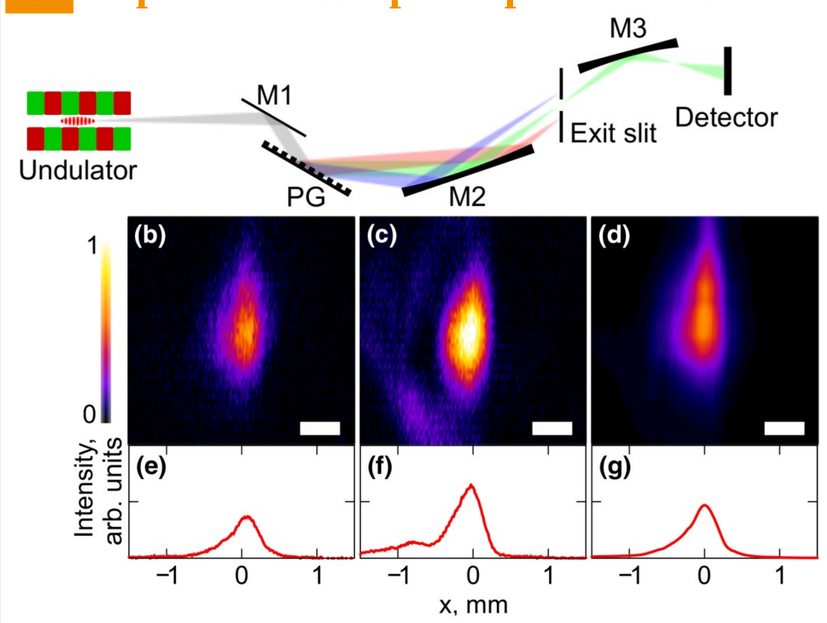
Hanbury Brown and Twiss demonstrated that statistical properties of a light source can be retrieved from measurements of intensity correlations [1]. Originally designed to determine star sizes, it has since been used for different applications, including studies of FEL sources [2]. Here we show results of extensive measurements performed at FLASH FEL at different wavelengths and accelerator conditions.

Theory

1. Correlation functions

Experiment

1. Experiment setup and parameters

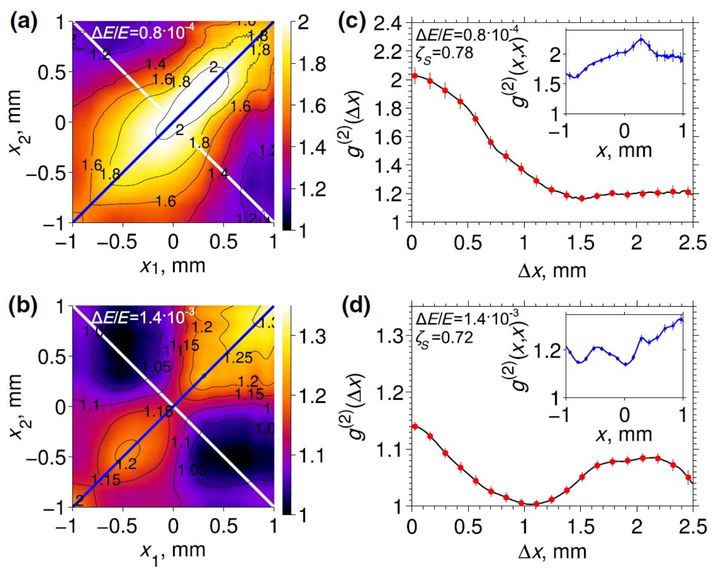


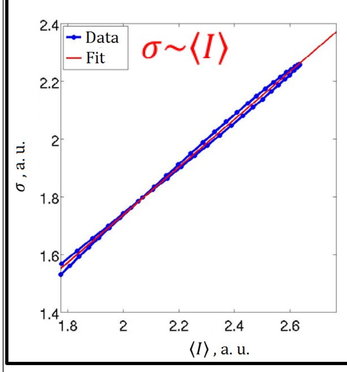
- Wavelengths 5.5 nm, 13.4 nm, 20.8 nm
- Bunch charges 0.6 nC, 0.06 nC and 0.2&0.5 nC respectively
- Monochromator to modify bandwidth (coherence time)
- 2D detector to measure high order correlation functions at different separations simultaneously

Wavelength 5.5 nm, ΔE/E = 0.8·10-4:
(b), (c) – typical pulses, (d) – average over 20000 pulses. (e) - (g) – their projections.

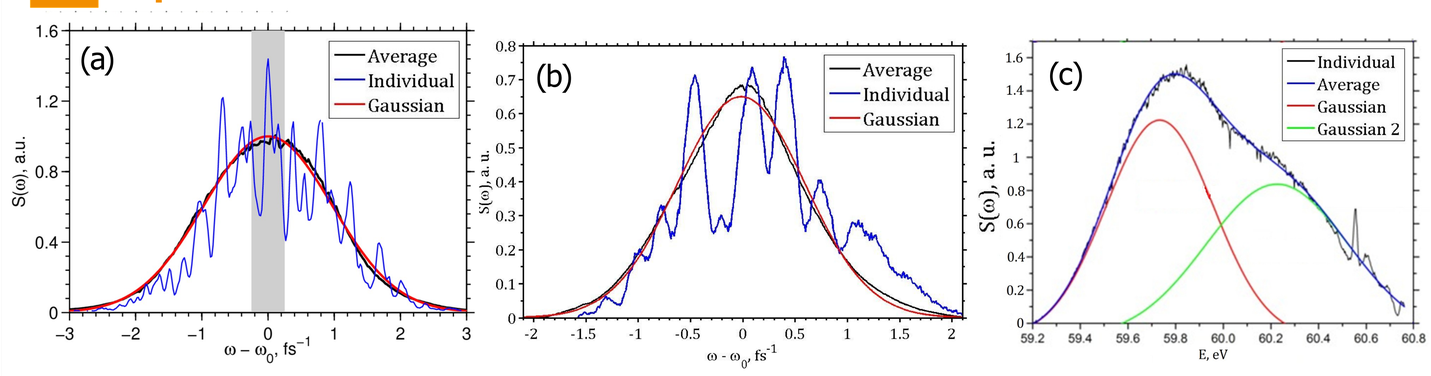
Features and Analysis

1. Intensity correlation analysis



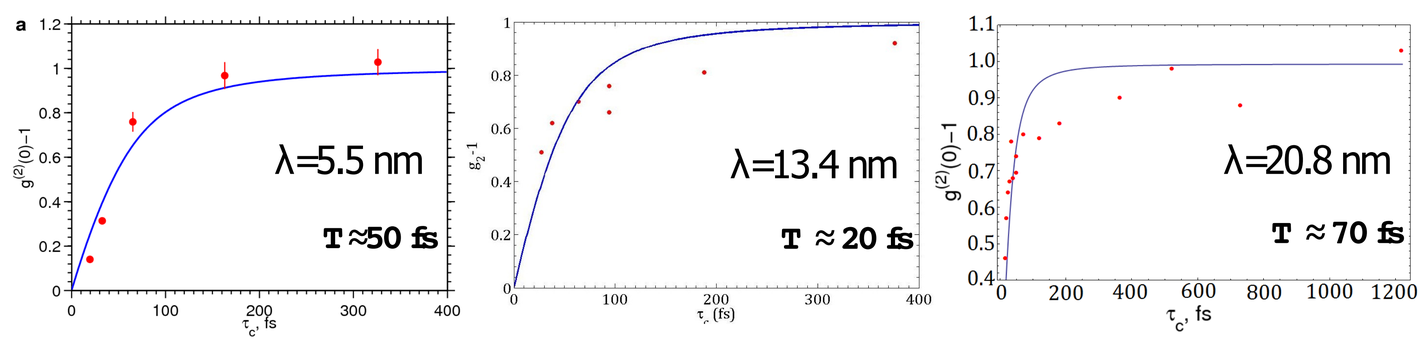


2. Spectra and modes



Typical spectra for different wavelengths and bunch charges.
Spectra of a single pulse, averaged and gaussian fit for (a) 5.5 nm wavelength, 0.6 nC bunch charge (b) 13.4 nm, 0.06 nC (c) 20.8 nm, 0.5 nC.
- The latter case corresponds to high bunch charge regime, which leads to a greater number of modes than expected and double peak.

3. Degree of coherence and pulse duration



Contrast as a function of coherence time for different wavelengths.
Pulse durations: (a) T ≈50 fs; (b) T ≈20 fs; (c) T ≈70 fs. (0.2 nC charge).

Summary

In summary, we conclude that change in wavelength produces changes in FEL spectrum statistical properties that confirm to theory. For all wavelengths, high contrast (close to 1) can be reached. Bunch charge can also affect FEL behavior significantly, leading to double-peak spectrum with excessive number of modes in one observed case.

References

[1] – Hanbury Brown and Twiss, Nature **177**, 27 (1956)
[2] – Singer et. al., Physical Review Letters **111** (2013)
[3] – Mandel and Wolf, *Optical Coherence and Quantum Optics*
[4] – Saldin, Schneidmiller and Yurkov, *The Physics of Free Electron Lasers*

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