NOVEL GRATING DESIGNS FOR A SINGLE-SHOT SMITH-PURCELL BUNCH PROFILE MONITOR

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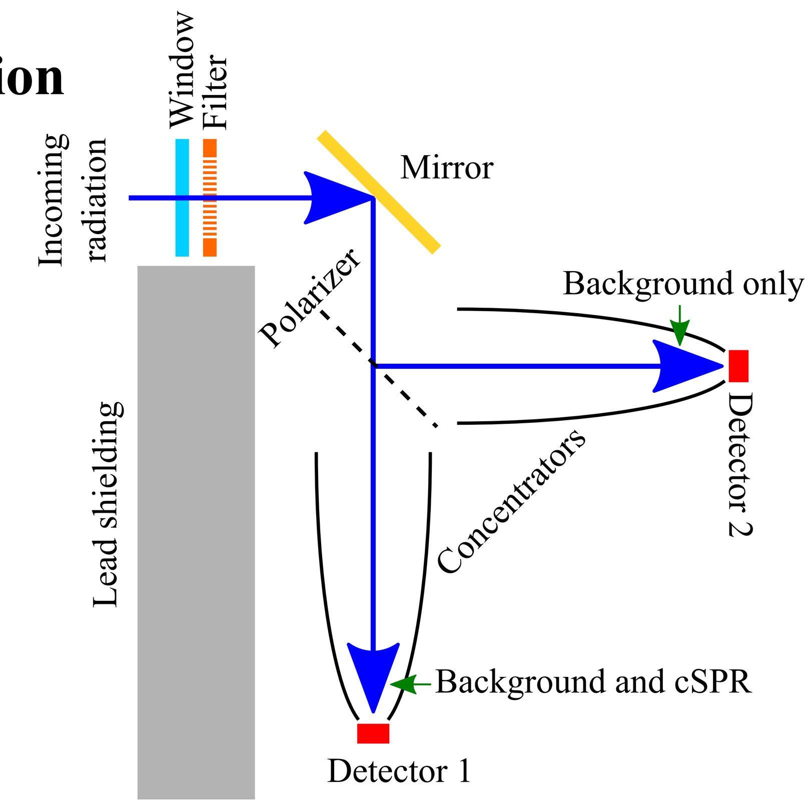
Smith-Purcell radiation has been successfully used to perform longitudinal profile measurements of electron bunches with sub-ps lengths [1]. These measurements require radiation to be generated from a series of gratings to cover a sufficient frequency range for accurate profile reconstruction. In past systems the gratings were used sequentially and so several bunches were required to generate a single profile, but modern accelerators would benefit from such measurements being performed on a bunch by bunch basis. To do this the radiation from all three gratings would need to be measured simultaneously, increasing the mechanical complexity of the device as each grating would need to be positioned individually and at a different azimuthal angle around the electron beam. Investigations into gratings designed to displace the radiation azimuthally will be presented. Such gratings could provide an alternative to the rotated-grating approach, and would simplify the design of the single-shot monitor by reducing the number of motors required as all of the gratings could be positioned using a single mount.

Single-shot longitudinal profile monitor: conceptual design

As particle accelerators advance the ability to determine the longitudinal bunch profile on a single-shot (bunch-by-bunch) basis is becoming increasingly important, and several approaches to the problem have already been developed [2-4]. We propose a system which uses coherent Smith-Purcell Radiation [5] as a single-shot diagnostic tool based on the E203 experiment at SLAC [1]. The constraints which needed to be overcome were the need for simultaneous background subtraction while maintaining the compactness of the device.

Background subtraction using polarization

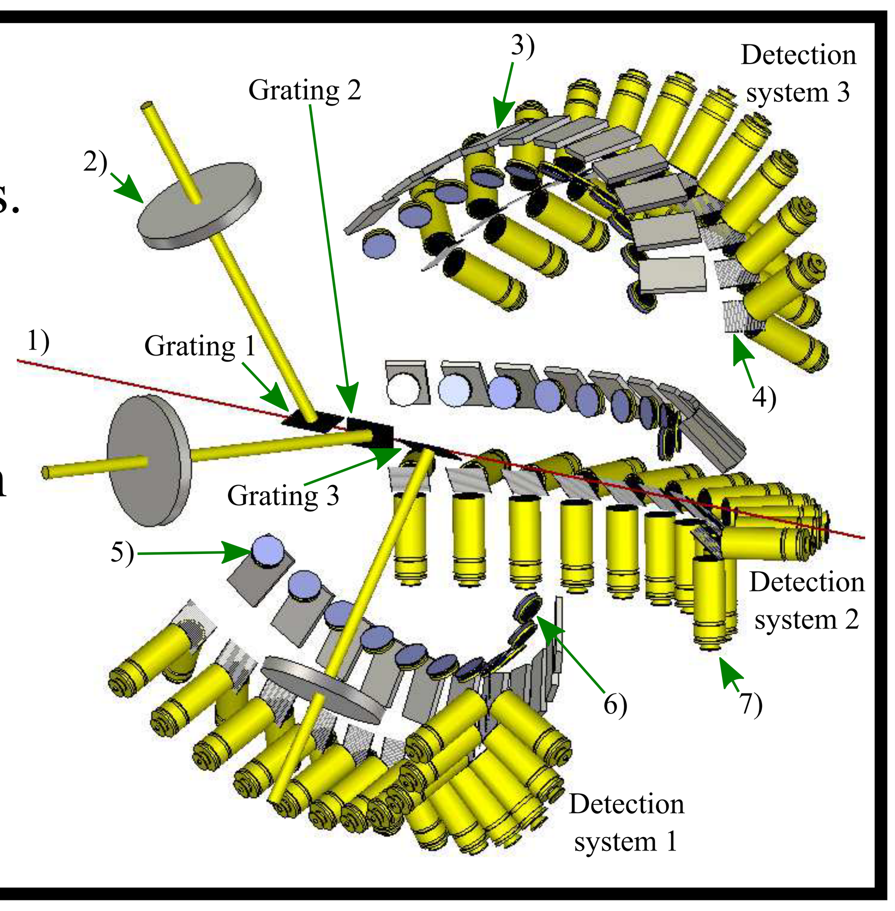
- Smith-Purcell radiation is predicted and measured to be highly polarized [6].
- Background radiation has been seen to be unpolarized [1].
- Splitting the radiation using a polarizer would enable bunch-by-bunch background subtraction.
- Background polarization properties must be measured for each accelerator.



Minimizing the device footprint

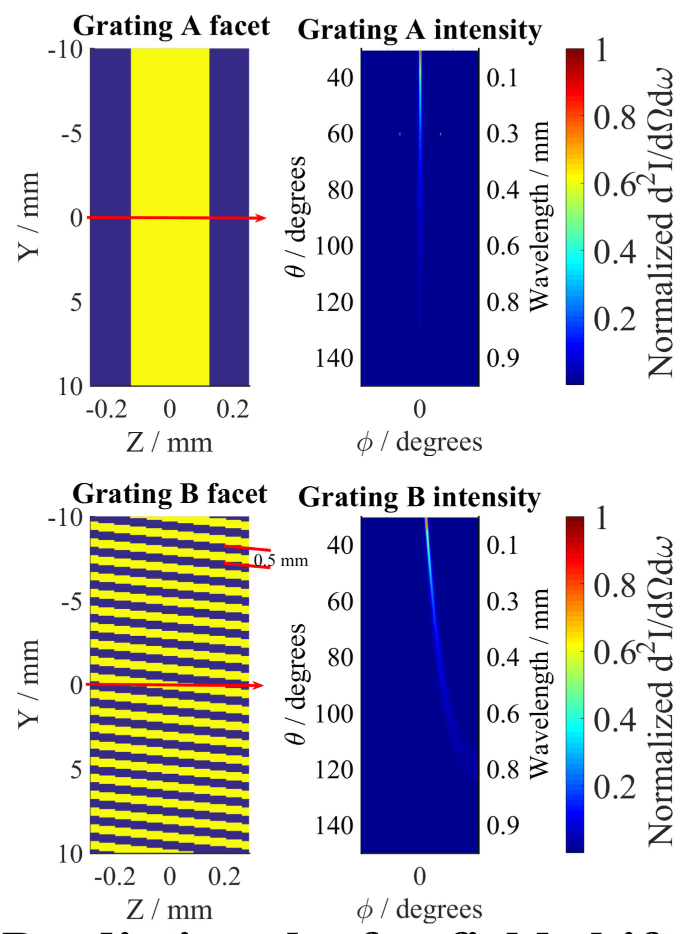
- The E203 device used 33 frequency measurements and 3 different gratings.
- Azimuthally rotating the gratings around the beam keeps the system compact.
- Requires 3 sets of motors and vacuum feedthroughs to position the gratings.

Components: 1) beam path, 2) vacuum feedthroughs, 3) mirrors, 4) polarizers, 5) vacuum windows, 6) filters and 7) concentrators and detectors. Grating 1 illuminates detection system 1. Components are to scale. Schematic drawn using CST Microwave Studio [7].



Alternative grating designs: simplifying the monitor

The key to the performance of the coherent Smith-Purcell radiation monitor is the number of frequencies which can be sampled, and so the number of gratings and detectors. By mechanically simplifying the device (e.g. by reducing the number of motors) more detectors could be added for a given budget.



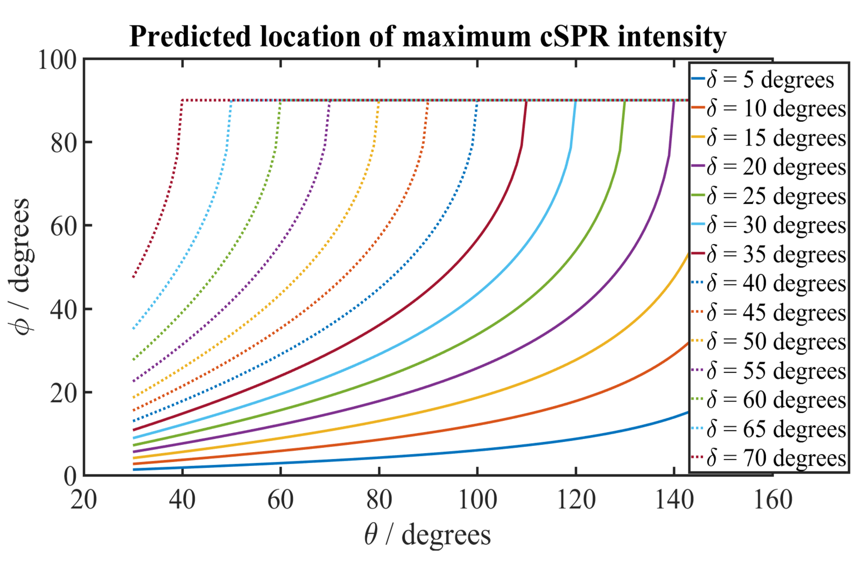
Rotating the grating period

- Standard gratings (e.g. grating A, left, yellow is conductor, blue is vacuum) need one motor each.
- The radiation is emitted along the ϕ-axis, as shown in the grating A intensity plot.
- Sergeeva et. al. predict that rotating the period of an infinite-width grating shifts the distribution in the azimuthal direction [8].
- Predictions must be made with finite-width gratings to be used in a bunch profile monitor.
- Calculations being performed using the NAG libraries [9]. Currently providing **qualitative** results.
- Grating B is rotated by 30 degrees to the beam.
- Intensity distribution clearly shifted azimuthally.

Predicting the far-field shift

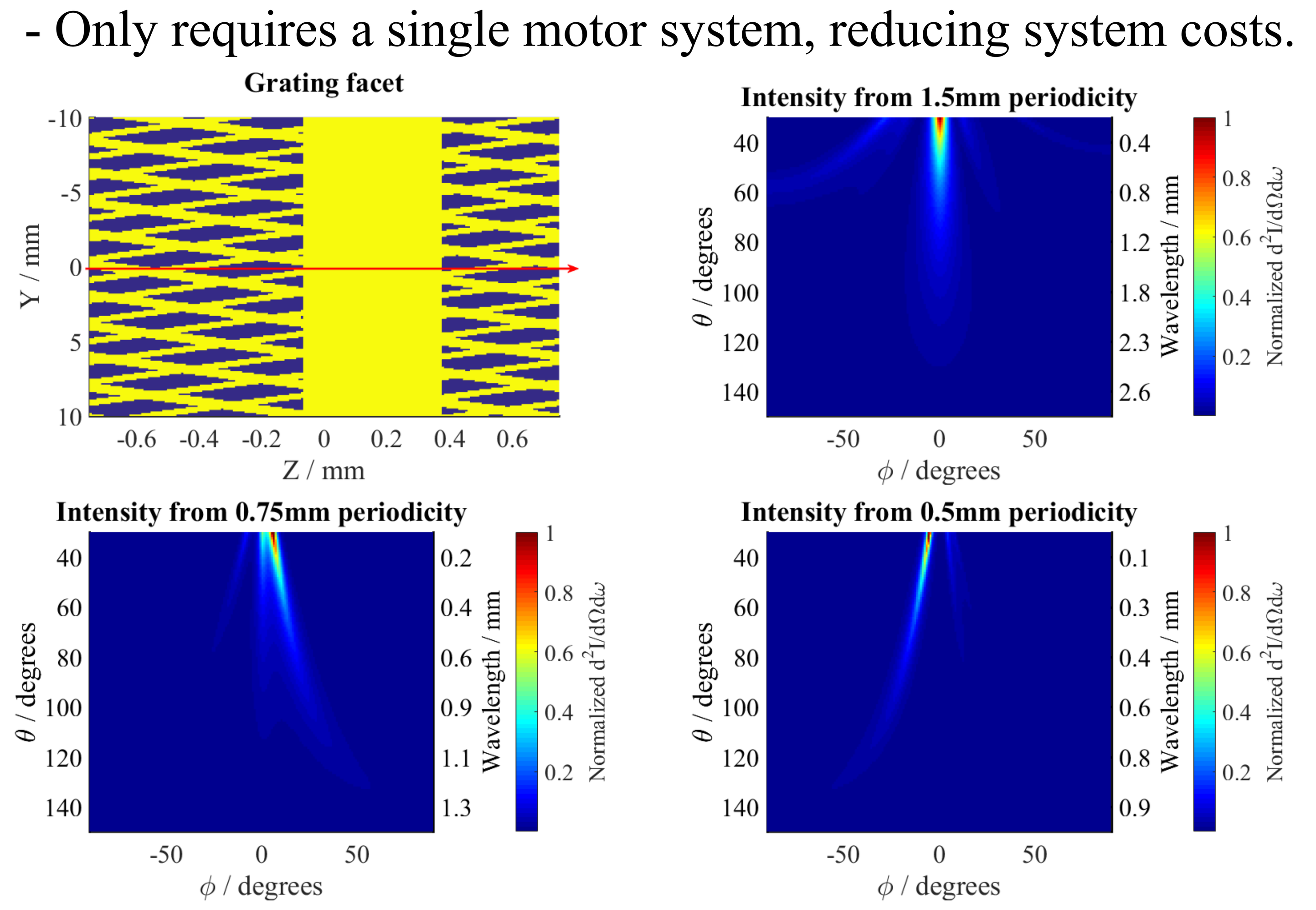
- Location of the peak can be predicted by equating the SPR dispersion relation with the grating dispersion relation along Y, as below.
- Predictions for gamma = 39000, n = m = 1.

SPR dispersion
$$\lambda = \frac{l}{n\cos\delta}\left(\frac{1}{\beta} - \cos(\theta)\right)$$
Grating dispersion
$$\lambda = \frac{l}{m\sin\delta}\sin\theta\sin\phi$$
Peak location:
$$\sin\phi = \frac{m\tan\delta}{n\sin\theta}\left(\frac{1}{\beta} - \cos(\theta)\right)$$



Combining multiple gratings

- Gratings with angled facets can be merged into a single design.
- Test grating (below) has three facet sizes:
  - 1.5 mm with no rotation.
  - 0.75 mm rotated by 20 degrees.
  - 0.5 mm rotated by -20 degrees.
- Intensity predicted to be spatially and chromatically separated.
- Single grating could be used for the single shot monitor.
  - Only requires a single motor system, reducing system costs.



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