Preliminary results for Smith-Purcell radiation from a skewed planar grating using the surface current model

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Overview

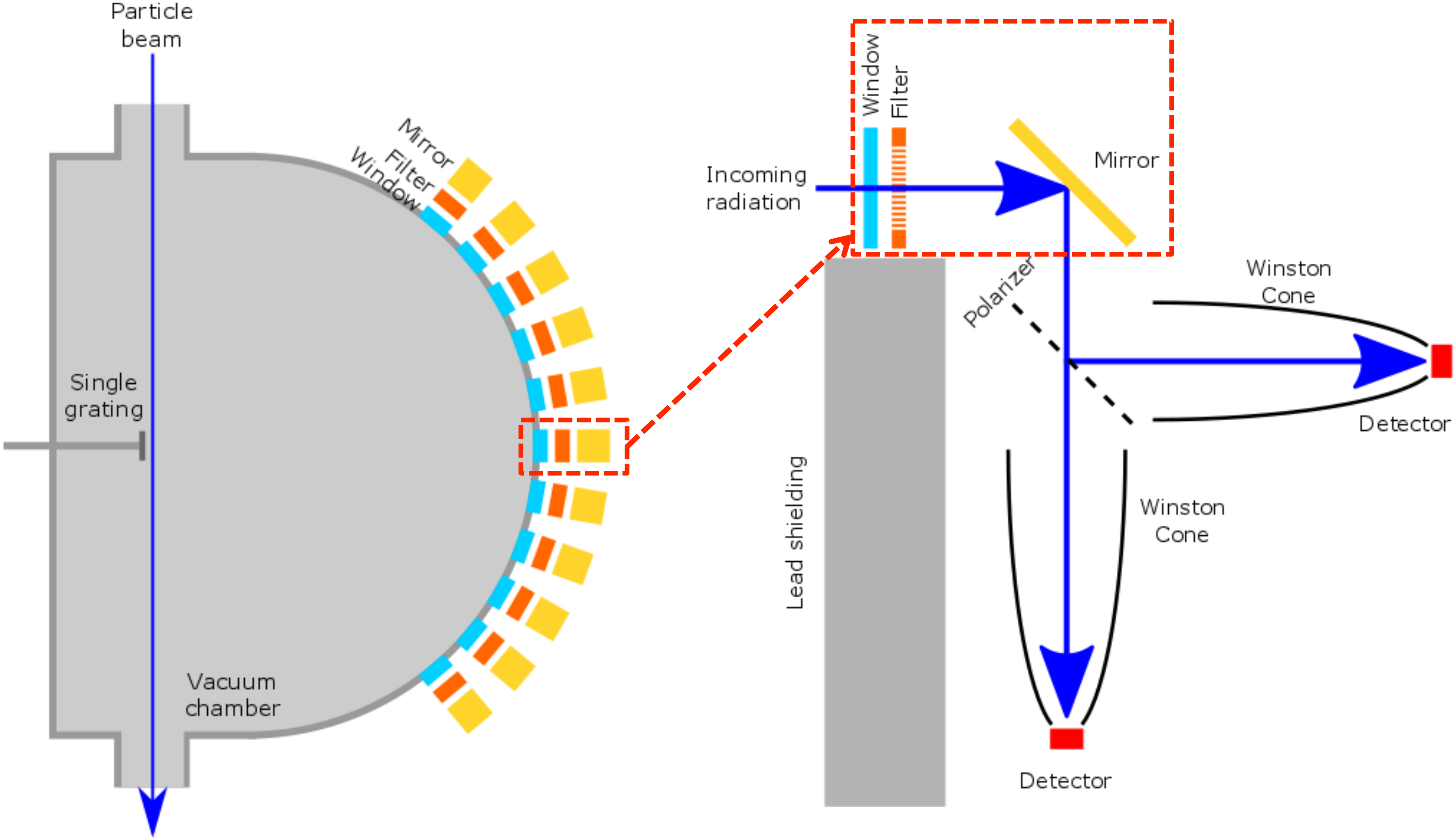
- Motivation
- Single-shot bunch profile monitor design
- Simplification by using skewed planar gratings
- Future plans

Motivation

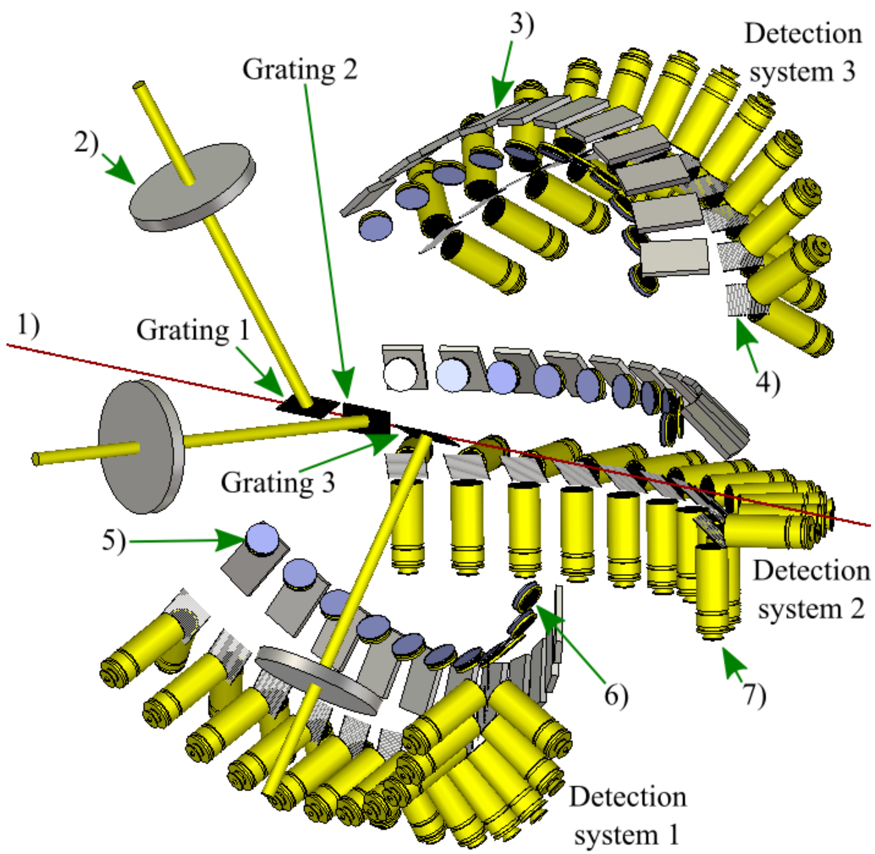
- Many applications require (or provide) short bunch lengths.
  - Particle colliders.
  - Plasma wakefield acceleration.
  - Free-electron lasers.
- Bunch profile can vary on a shot-by-shot basis.
- Complex interactions can be difficult to model.
- Better to simply measure the beam!
  - Needs to be non-destructive.
  - Needs to provide a bunch profile for every bunch.
- Coherent Smith-Purcell radiation is a viable solution*.
  - Longitudinal bunch profile encoded within the intensity distribution.
  - Different radiation frequencies spatially separated because of grating.

*H. L. Andrews et al., Phys. Rev. ST Accel. Beams, vol. 17, pp. 052802, 2014.

Overview of the design



Overview of the design



1. Beam path
2. Vacuum feedthrough
3. Mirrors
4. Polarizers
5. Vacuum windows
6. Filters
7. Concentrators and detectors

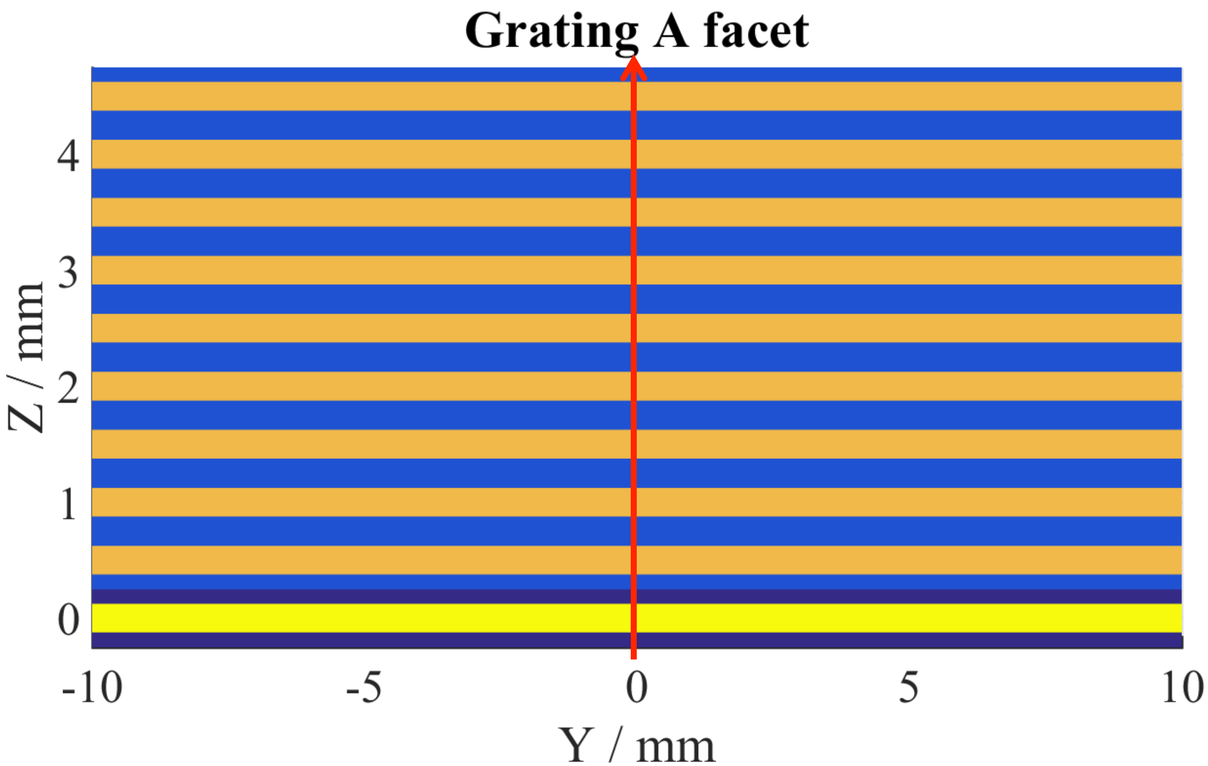
Model produced using CST Microwave Studio

Qualitative model

- Based on surface current model*.
  - Currents calculated using the method of images.
- User specifies:
  - Grating facet design.
  - Grating periodicity.
  - Electron position and propagation direction.
- Integrals calculated using the NAG libraries.
- Current limitations:
  - Single particle only.
  - Surface current only defined directly below the particle.

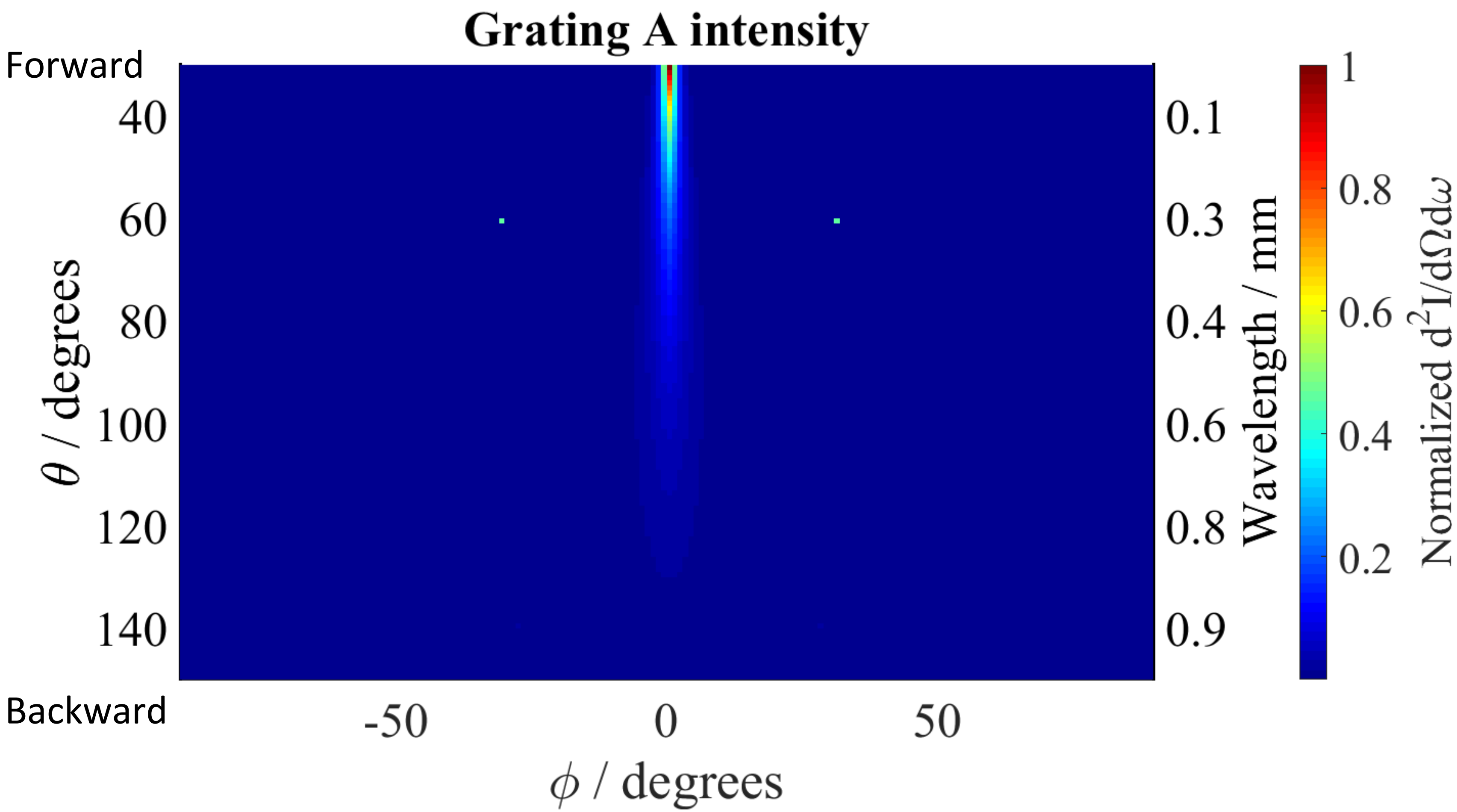
*J. Brownell et. al., Phys. Rev. E, vol. 57, no. 1, pp. 1075-1080, 1998.
A. P. Potylitsyn et. al., Diffraction Radiation from Relativistic Particles (Springer, Berlin, 2011).

Basic grating

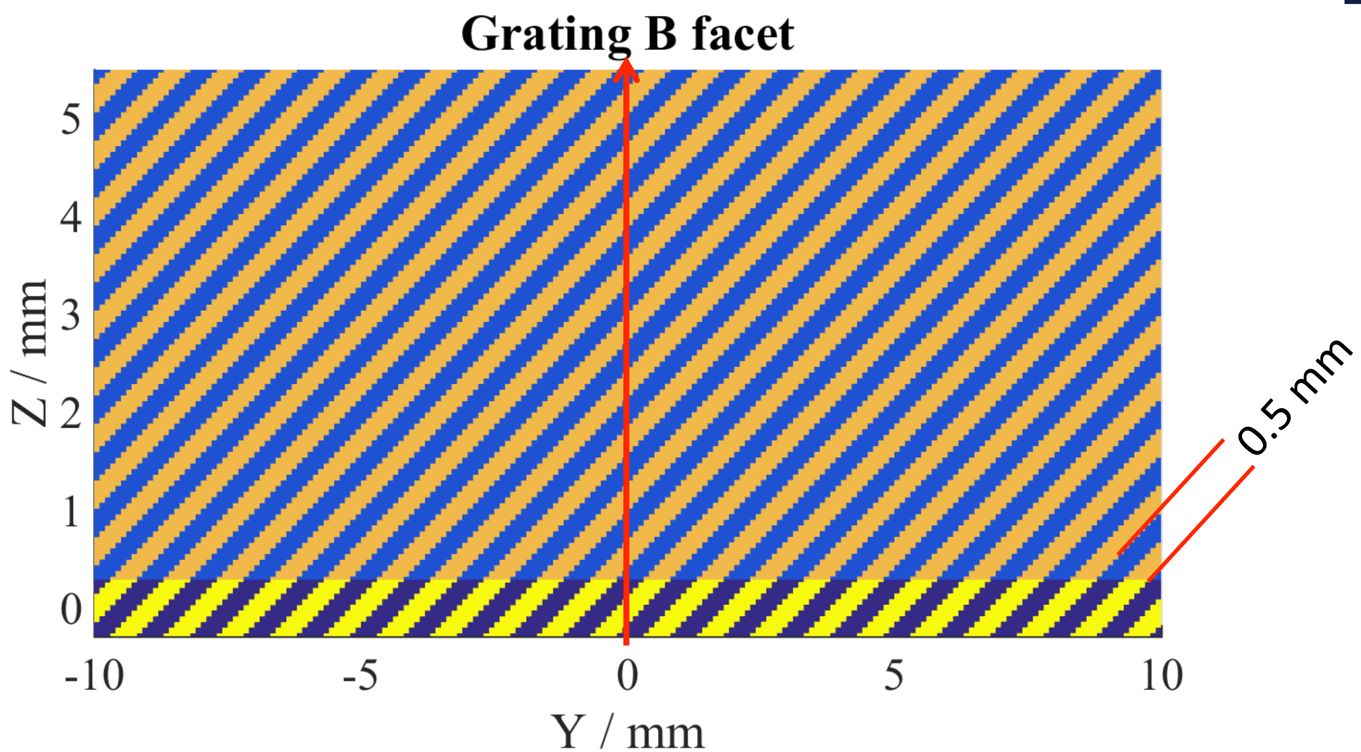


Particle γ =39,000, grating period = 0.5 mm, beam height = 1mm, 120 periods.
Beam direction shown by the red arrow.

Basic grating



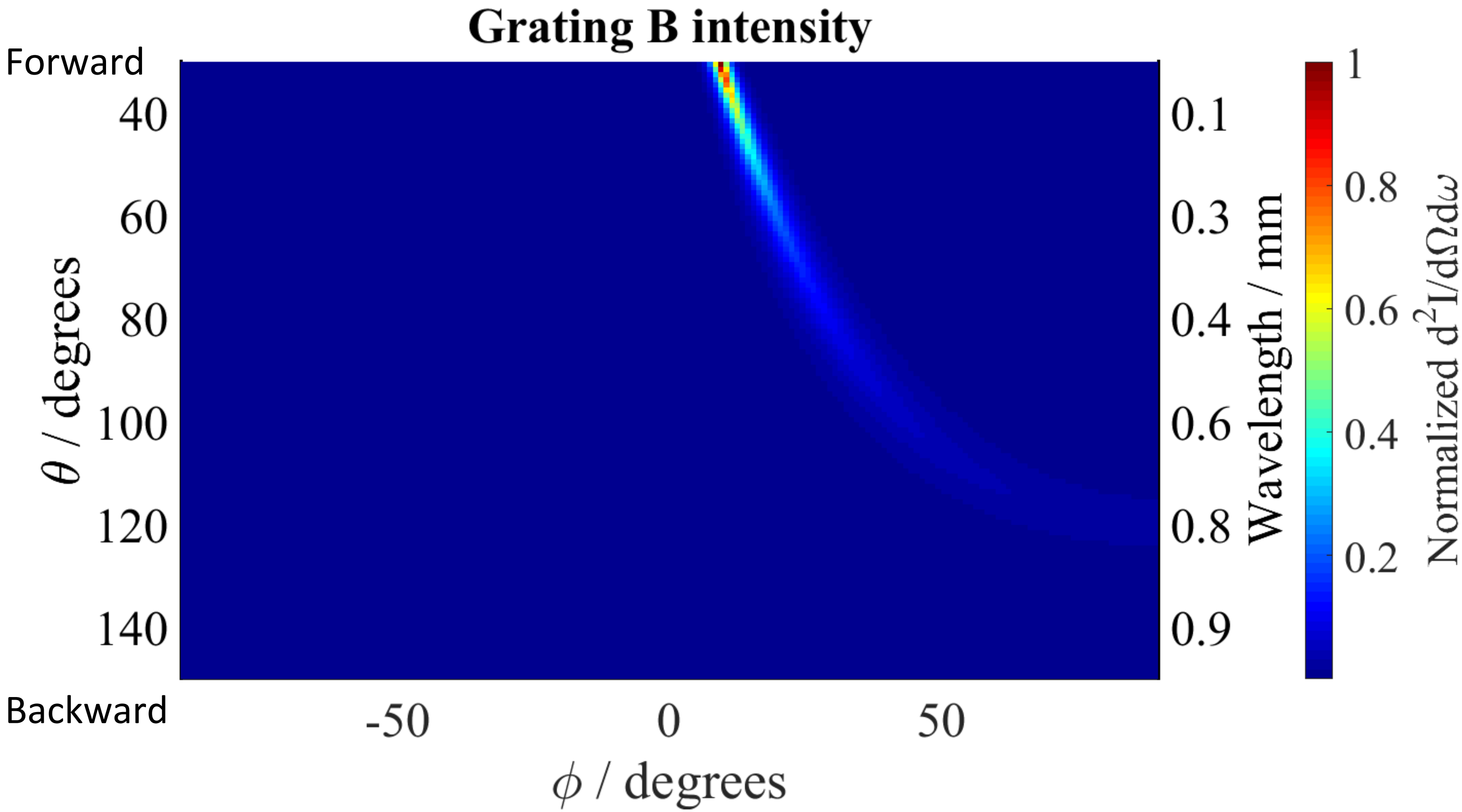
Skewed grating



- 30 degree skewed grating (based on the work by Sergeeva et. al.*).
- Rulings have 0.5 mm period, giving a facet length of 0.5/cos(30) = 0.577 mm.
- Particle γ =39,000, beam height = 1mm, 120 periods. Beam direction in red.

*D. Yu. Sergeeva et. al., Phys. Rev. ST Accel. Beams, vol. 18, pp. 052801, 2015.

Skewed grating



Optical prediction

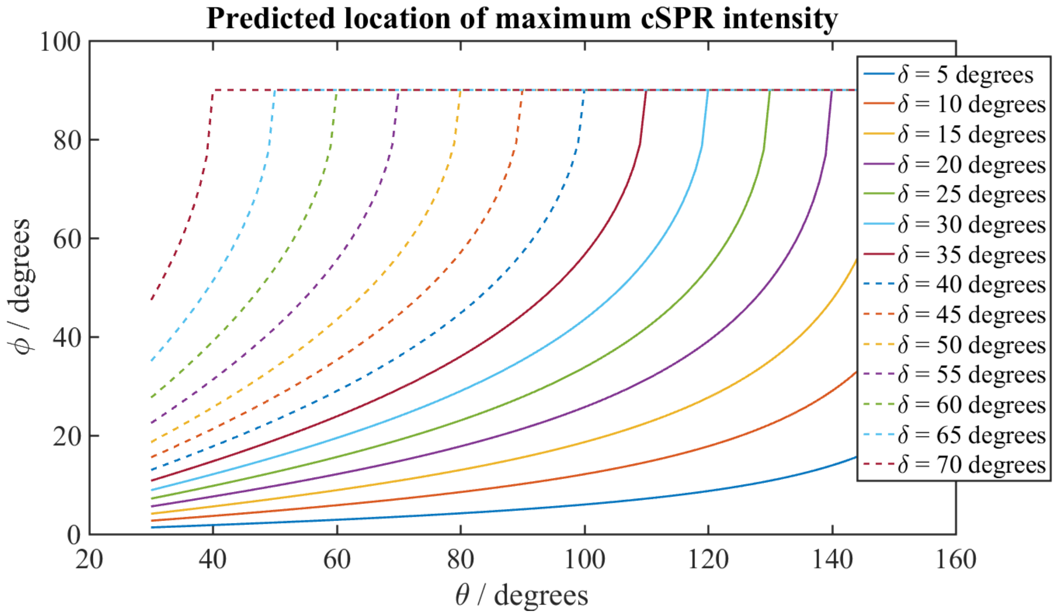
SPR dispersion relation

$$\lambda = l/N cos(\delta)\ (1/\beta - \cos(\theta))$$

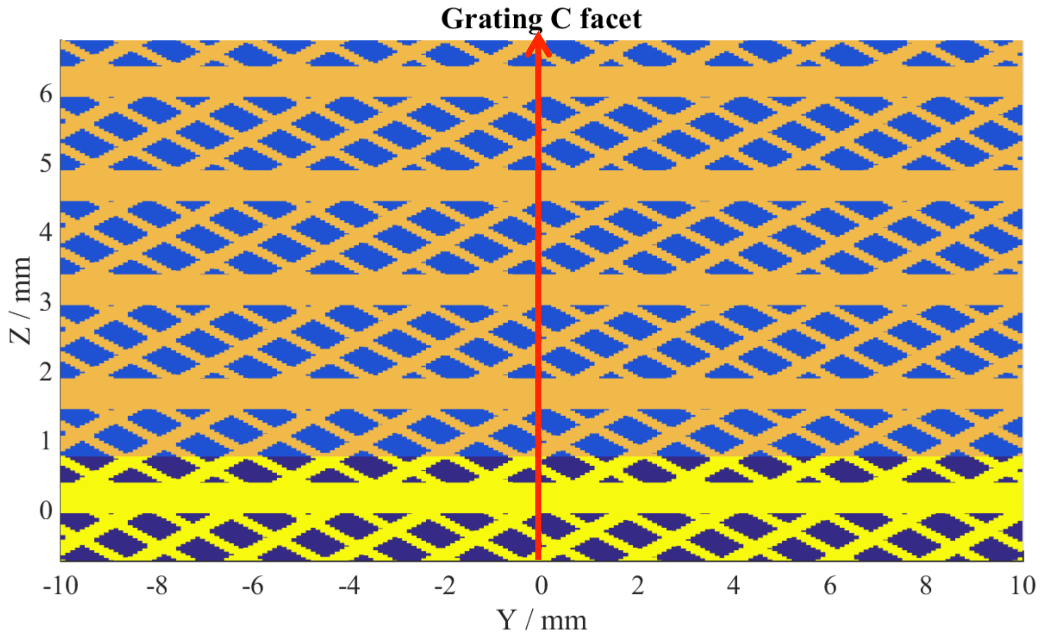
Y-grating effect

$$\lambda = l/M sin(\delta)\ \sin(\theta)\ \sin(\phi)$$

$$\boxed{\sin(\phi) = M tan(\delta)/N sin(\theta)\ (1/\beta - \cos(\theta))}$$

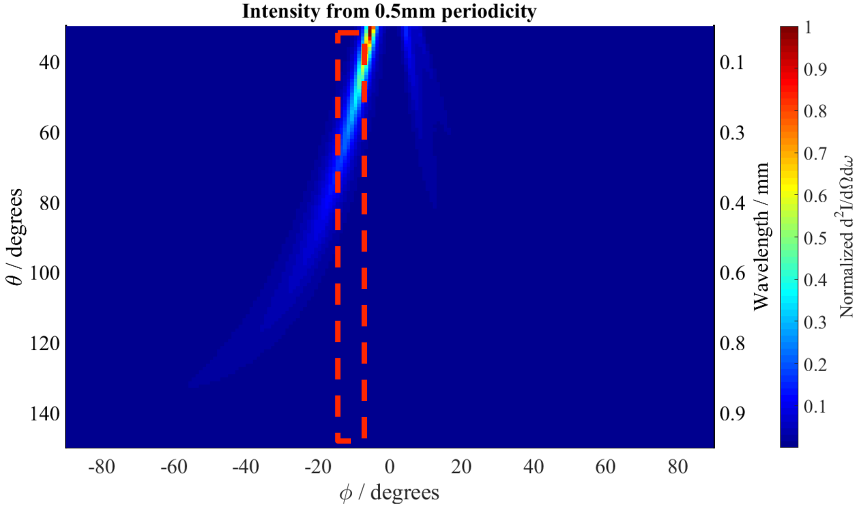


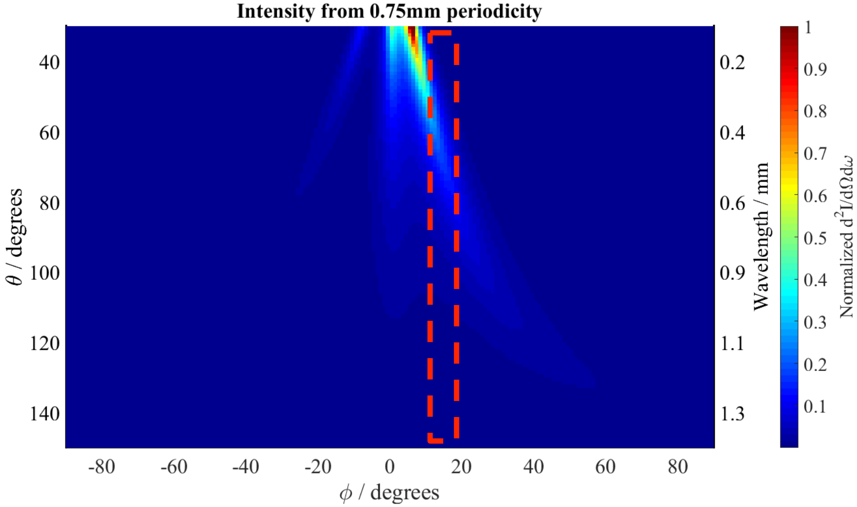
Combined grating

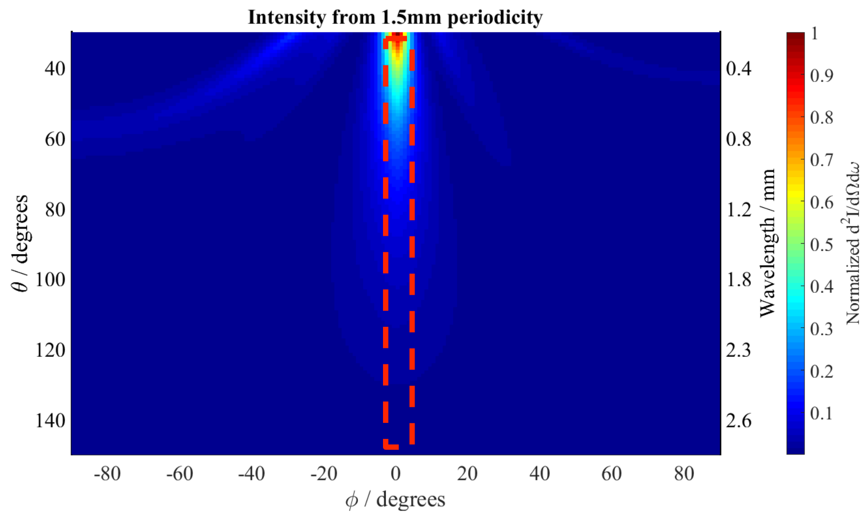


- Superposition of three gratings:
  1. Un-skewed grating with periodicity of 1.5 mm.
  2. 20 degree skewed grating with a facet length of 0.75 mm.
  3. -20 degree skewed grating with a facet length of 0.5 mm.
- Particle γ =39,000, beam height = 1mm, 40 periods. Beam direction in red.

Combined grating







Summary

- Outline of a single-shot SPR beam profile monitor.
- Discussion of new grating designs to simplify the system.
- Further work:
  - Need quantitative predictions.
  - Further modify the radiation distribution, suggestions welcome!
- Any new grating would require extensive study before use.
  - Intend to build system with un-skewed gratings.
  - Test new grating designs during development runs.
- More detail available in proceedings of IBIC 2016 (MOPG62).

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