Novel Approach to the Elimination of Background Radiation in a Single-Shot Longitudinal Beam Profile Monitor

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New developments in particle accelerators create a demand for up-to-date diagnostic tools. At facilities with short (fs) bunches there is a need for a non-destructive single-shot longitudinal bunch profile monitor. Coherent Smith-Purcell radiation (cSPr) has been shown to be a useful tool for monitoring the longitudinal profile of electron bunches [1], however, no single-shot monitor using cSPr has been built or designed. One challenge that must be overcome in such a monitor is the elimination of background radiation, which can be comparable with the cSPr signal in high-energy accelerators [1]. We propose to use the polarization of cSPr to separate it from the background radiation, however, this requires the polarization of cSPr to be well understood.

Theory

Smith-Purcell radiation is emitted when a charged particle travels above a periodic grating. The charge induces a surface current on the grating surface which emits radiation that is spatially distributed according to the dispersion equation:

$$\lambda = \frac{l}{n}\left(\frac{1}{\beta} - \cos\theta\right) \qquad (1)$$

λ is the emitted wavelength, θ is the observation angle (relative to the beam direction), β is the electron velocity, l is the grating periodicity and n is the order of emission. Among the theories put forward to describe cSPr [2, 3] is the Surface Current Model (SCM) [4].

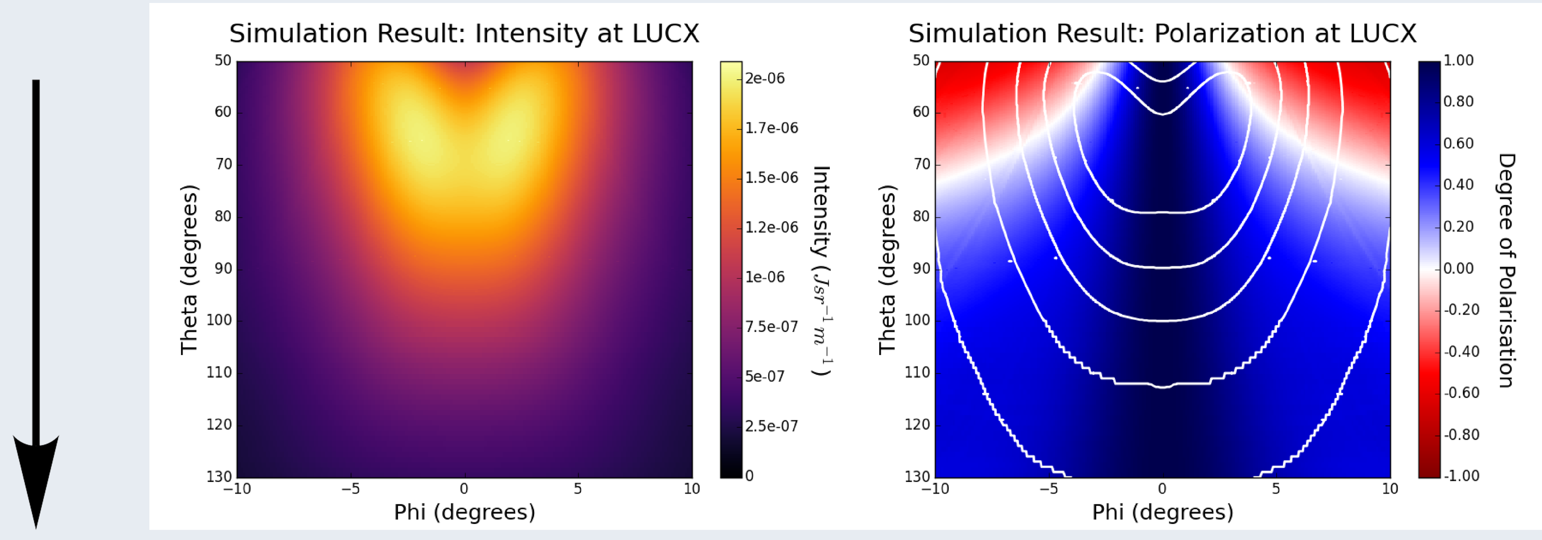

Figure 1 : Simulation of the intensity and degree of polarization, of cSPr generated by a 8 MeV electron bunch interacting with a 1 mm grating. θ is the observation angle along the beam line, ϕ is the azimuthal angle around the beam line. The arrow (far left) gives the direction of the beam.

cSPr has been shown to be polarized [1, 5, 6], however, there has not been an extensive study to compare it with the theoretical model.

Experimental Layout

Parameter	Expected values
Beam energy, typ	8MeV
Intensity/bunch, max	50pC
Bunch length	0.15ps to to 10ps
Repetition rate (single bunch), max	12.5Hz
Normalized emittance, $\epsilon_x \times \epsilon_y$	4.7×6.5 πmm mrad

Table 1 : LUCX, beam parameters

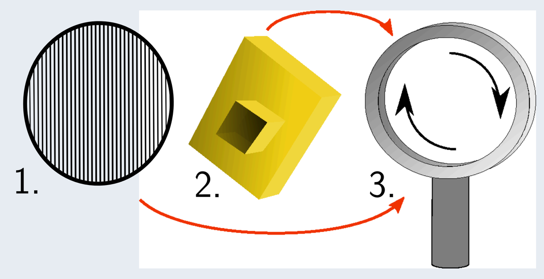

Figure 2 : 1. Wire Polarizer, 2. Detector, 3. Rotating Stand. The detector and polarizer are bolted to the rotating stand.

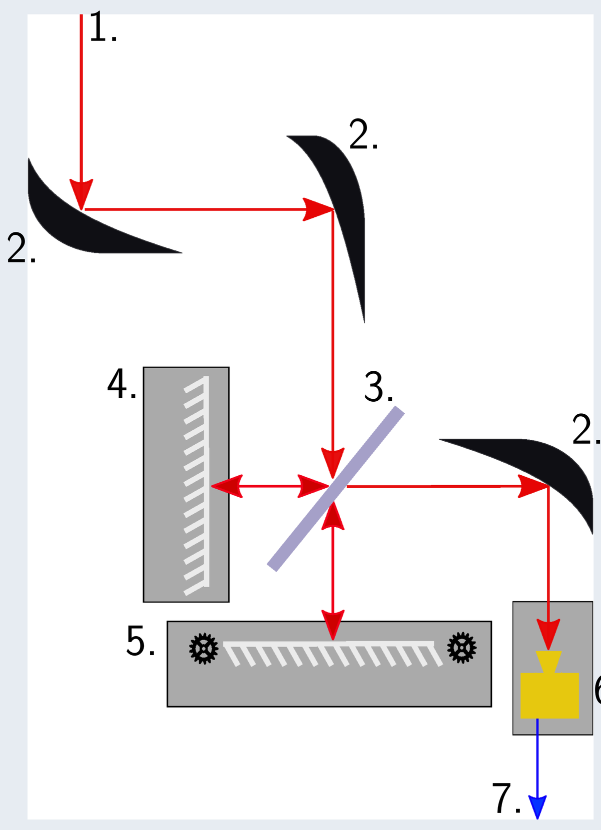

Figure 3 : 1. Radiation from THz Chamber, 2. Parabolic Mirror, 3. Beam Splitter, 4. Plane Mirror, 5. Motorised Stand, 6. Detector, 7. Signal to ADC.

The experiment was carried out at the LUCX facility, KEK, Japan (Table. 1) [7, 8] using a grating with a periodicity of 1mm to generate the cSPr. An interferometer (Fig. 3) was used to determine that cSPr was being produced (narrowband with a peak at 300GHz)[9]. To measure the polarization the rotating detector setup (Fig. 2) was used, the constant angle between the detector and the polarizer eliminate polarization dependency of the detector from the results. The detector was rotated almost 360°, measurements were taken at 2° intervals.

Results and Discussion

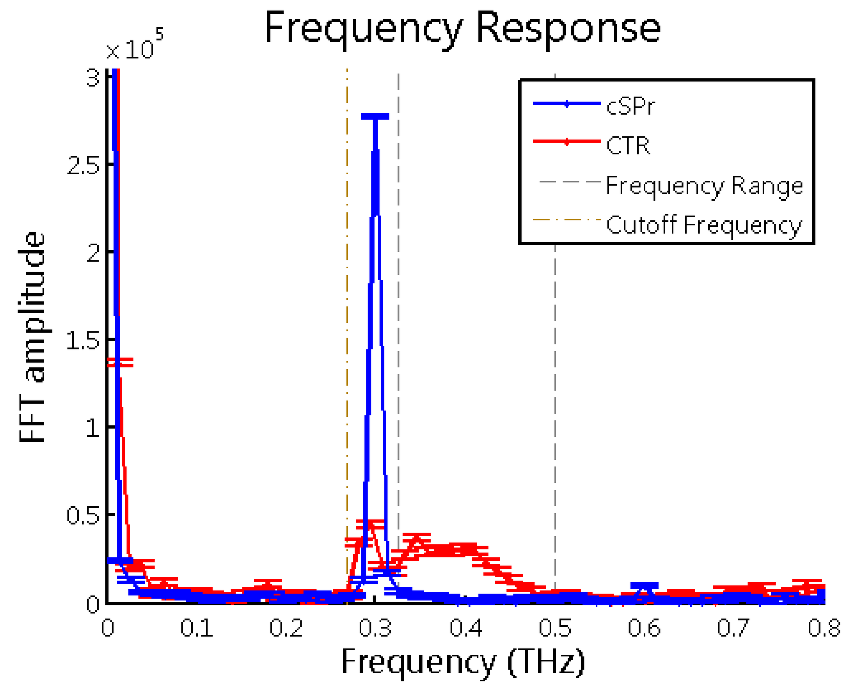

Figure 4 : Frequency spectrum of cSPr compared with broadband CTR.

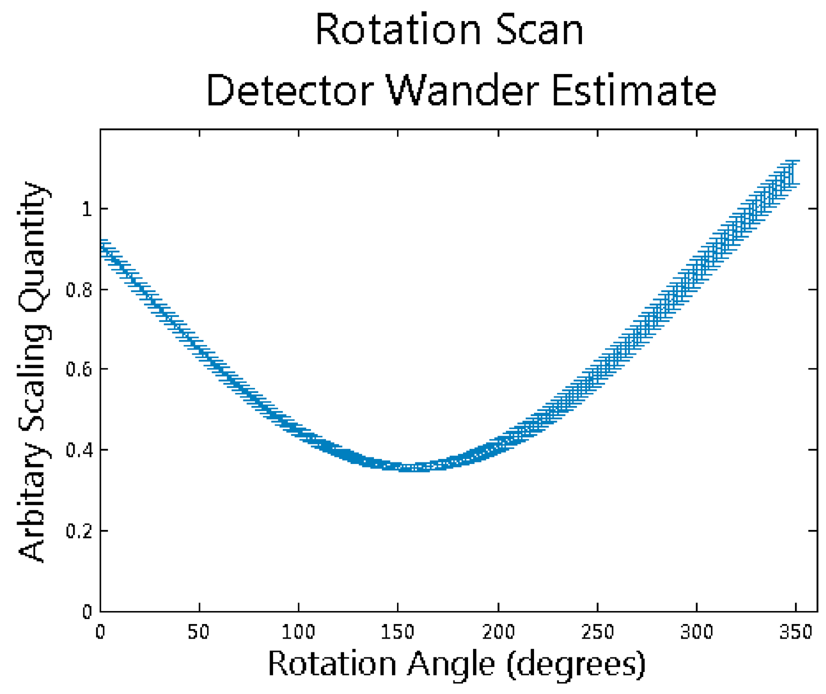

Figure 6 : The variation in the signal due to detector misalignment.

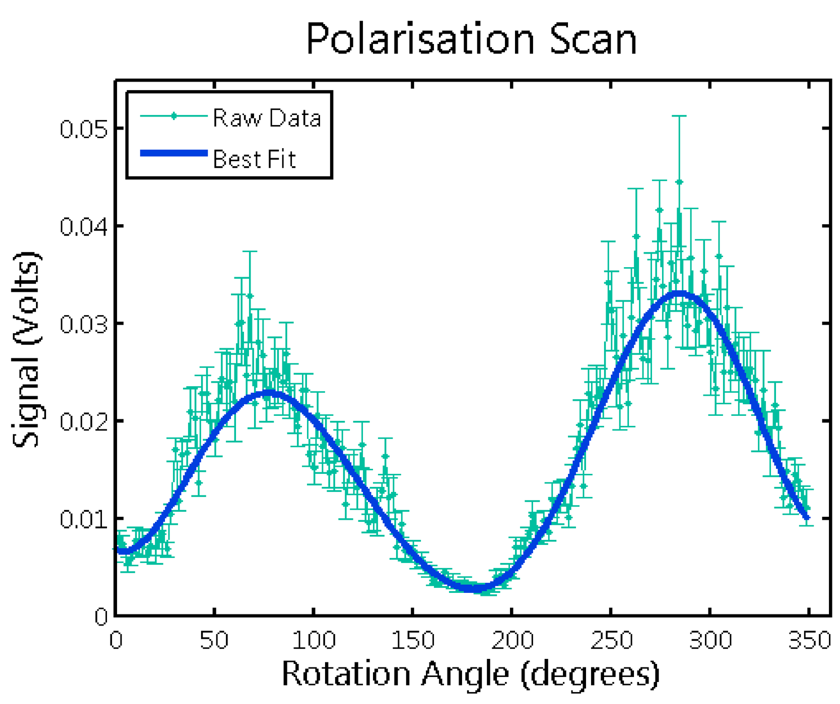

Figure 5 : Measured raw data for a 360° rotation of the detector and polarizer.

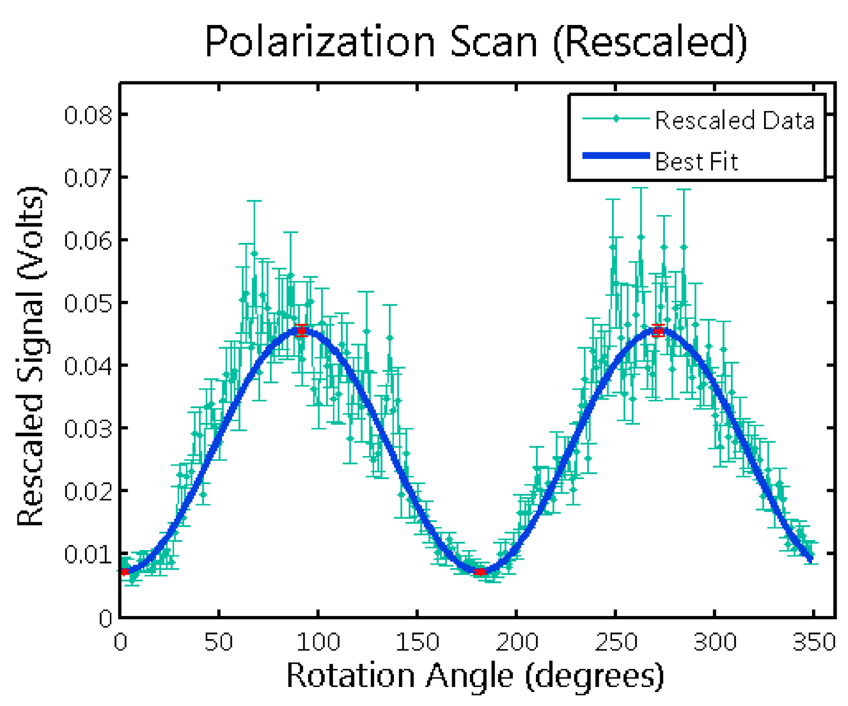

Figure 7 : The rescaled data for a 360° rotation of the detector and polarizer.

- Figure 4 shows that the cSPr generated at LUCX is narrowband compared to the detector response [10].
- The raw data for a rotation scan is shown in Fig. 5. The maxima and minima are uneven due to detector misalignment.
- Using a fitting routine the variation in intensity due to detector misalignment was extracted from the raw data (Fig. 6). The rotation scan is replotted in Fig. 7 and rescaled with respect to this variation.
- The degree of polarization is calculated from Fig. 7 as $72.6 \pm 3.7\%$.

$$p_g = \frac{G_\parallel - G_\perp}{G_\parallel + G_\perp} \qquad (2)$$

The degree of polarization of cSPr p_g is calculated as shown in Eq. (2) where G_i is the cSPr signal and $\parallel$ and $\perp$ are the two orientations of the radiation with respect to the grating grooves, corresponding to the maxima and minima of Fig. 7.

- This value for the degree of polarization is an underestimate as the value of the noise floor and acceptance angles $\delta\theta$ and $\delta\phi$ of the detector were unknown.
- To make a comparison with the theoretical model (Fig. 1) the polarization of cSPr will have to be measured at more frequencies.

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Acknowledgments

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