Q-FACTOR OF AN OPEN RESONATOR FOR A COMPACT SOFT X-RAY SOURCE BASED ON THOMSON SCATTERING OF STIMULATED COHERENT DIFFRACTION RADIATION

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Abstract
High-brightness and reliable sources in the VUV and the soft X-ray region may be used for numerous applications in such areas as medicine, biology, biochemistry, material science, etc. We have proposed a new approach to produce the intense beams of X-rays in the range of $\hbar\omega \leq 500$ eV based on Thomson scattering of Coherent Diffraction Radiation (CDR) on a 43 MeV electron beam. CDR is generated when a bunch of charged particles moves in the vicinity of an obstacle if a radiation wavelength is comparable to or longer than the bunch length. In our case the CDR is generated by bunches passing through holes in two mirrors formed an open resonator. In this report the status of the experiment, the first CDR measurements at the multibunch beam of the LUCX facility and general resonator tuning procedure will be reported.

INTRODUCTION

CDR is generated when a charged particle moves in the vicinity of an obstacle. The radiation is coherent when its wavelength is comparable to or longer than the bunch length. The CDR waves were generated by a multi-bunch beam of the LUCX facility and accumulated in an open resonator formed by two mirrors (the first one was flat and the second one was concave) [1]. In [2] we have demonstrated the first observation of Stimulated CDR (SCDR), i.e. if the cavity length is equal to a half of the bunch separation in a train (while the rest of the axes are well aligned) and the decent amount of power is stored in the resonator, every subsequent bunch generates radiation in a presence of a strong field that leads to stimulation of the CDR emission. In this paper we represent further investigations of SCDR properties.

In our recent reports [1, 3] we have demonstrated the status of the project on development of a novel soft X-ray source based on inverse Thomson scattering of Coherent Diffraction Radiation. We have represented the first CDR measurements at the multibunch beam and demonstrated the performance of the fast millimeter wavelength registration system based on the Schottky Barrier Diode (SBD) detector and presented detailed discussion on microwave resonator design. In this report we shall represent the current status of the project including tuning experience of the microwave resonator.

EXPERIMENTAL APPARATUS

The experiment has been performed at the LUCX facility which has not been changed since last reported [4, 5] and will not be described here. The main LUCX beam parameters are summarized in Table1.

Energy	43MeV
Intensity	1nC/bunch
Number of bunches	100
Bunch spacing, ns	2.8
Bunch length, ps	10
Repetition rate, train/s	up to 12.5
Normalized emittance(πmm mrad)	5 x 5

Table 1: LUCX Beam Parameters

Figure 1 represents schematic diagram of the LUCX beam line. The multi-bunch electron beam generated by the 1.5 cell RF gun is accelerated up to 43MeV by the 3-m S-band accelerating structure. After that electron beam passes through the CDR open resonator made of two mirrors. The first mirror is flat fused silica glass with 5 mm free opening for the beam. The second mirror has a spherical concave surface with radius of 840 mm and made of bulk aluminum with 5 mm free opening in its center.

Small fraction of microwave radiation power is extracted through the discontinuity in aluminium layer of the upstream target and detected by the SBD detector capable of resolving the CDR photons produced by each

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bunch in the train in order to monitor power build-up (typical oscilloscope trace of the SBD detector and corresponding trace of the Inductive Current Transformer (ICT) is shown in [3], Fig. 3 therein).

Two large aperture fused silica vacuum windows were introduced to transmit microwave power out of the chamber in upstream direction and (in a future) to extract scattered UV/visible photons in downstream direction. Also both view-ports are used for alignment procedure involving alignment laser installed onto the same optical rail as SBD detector and allowing us to verify microwave path and CDR mirrors alignment. To align the targets with respect to electron beam a colorimeter gamma detector is placed close to the detector of the scattered photons (see Fig.1 sub-frame). Both detectors are based on Hamamatsu 1161 PMT. Hoshin 16 bit CAMAC ADC was used for digitization of gamma detector signal.

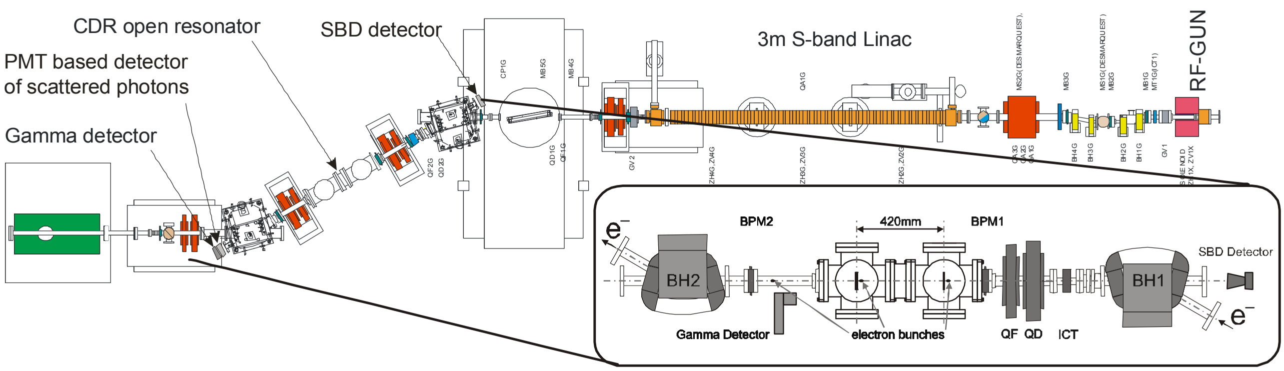

Figure 1: LUCX schematic layout and general experimental setup.

MICROWAVE RESONATOR TUNING

Each mirror of the open resonator is mounted on multi-axes (XYZ, and rotation in X-Z plane[#]) vacuum manipulation system. Which is installed into 6-way crosses separated by a custom made nipple to keep correct (420 mm) distance between the centres of the mirrors (Fig. 1). The in-vacuum mirror mounts are designed to accept 100 mm diameter and minimum 3 mm thickness mirrors and has two manual adjusters: angular (±5° in Y-Z plane) and linear (±1.5 mm in Y-Z plane). Adjusters are made in order to align the aluminium surface of the mirrors with respect to the rotation axis of the manipulator. Since both manipulators were installed from the tops of 6-way crosses, they both gave us ability to rotate each mirror in X-Z plane only. In order to align each mirror in Y-Z plane we used manual adjuster and well-known back-reflection technique when alignment laser light was sent through the centre of the vacuum chamber and was reflected back from each mirror to produce light spot at the same reference point (vacuum window centre) as incoming laser beam. This procedure sets two mirrors almost parallel to each other and perpendicular to the vacuum chamber centre path, so in real experiment we always kept electron beam vertical trajectory as flat and centred as possible.

During experimental beamtime after initial beam tuning and electron beam optics verification the dependences of bremstrahlung measured by gamma detector versus horizontal and vertical mirror position are usually acquired. Note that the vertical scan is taken in horizontal mirror position corresponded to the minimum bremstrahlung signal. Fig. 2 represents a typical upstream mirror scans. One can see that dependences has a relatively sharp edges what allows to conclude that electron beam core is definitely passing through the mirror without interaction with mirror material.

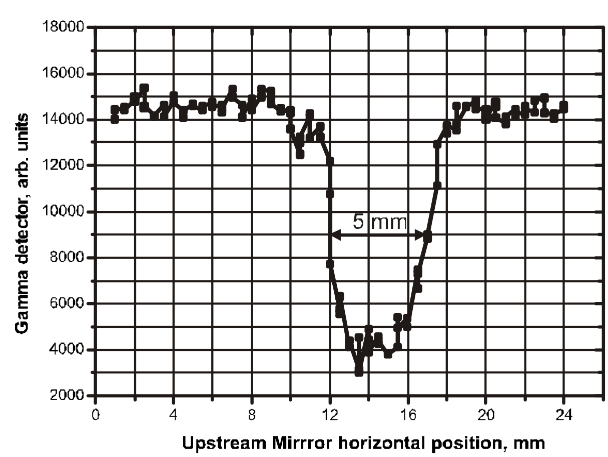

Figure 2: Dependences of bremstrahlung measured by gamma detector versus horizontal mirror position.

After horizontal and vertical mirror positions were set to match the centre of penetration holes and the centre of electron beam, the angular dependence of CDR was taken. SBD detector is sensitive to only one polarization of incoming electromagnetic wave and its position was set to register polarization in X-Z (rotation) plane of mirrors. The best angular position of each mirror corresponds to the dip in between two lobes of the

[#]accelerator coordinate system is used dependence that sets the mirror to be perpendicular to resonator axis [2]. The same scanning algorithm was applied to the downstream mirror.

It is worth to mention that angular dependences of each mirror were taken with aluminium surface oriented towards SBD detector and for the resonator tuning upstream mirror has to be rotated on 180 degrees from its best position according to the angular scan.

After each mirror was set to its best position extracted from X-Y and angular scans one can obtain power stacking in a cavity appearing in SBD signal (see Fig. 3) as amplitude increase within beam train duration and decaying spikes of the microwave power after last bunch in a train representing cavity free run. When the resonator is misaligned, i.e. its length is not exactly a half a distance between bunches, the resonance disappears.

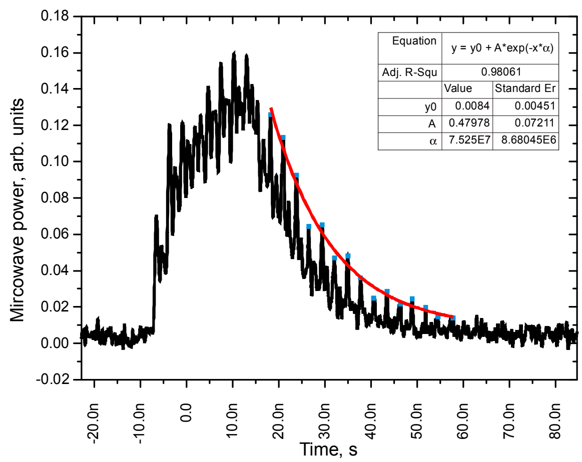

Figure 3: SBD Scope trace.

The tail of the signal contains information about the radiation stored in the cavity. One may see when the resonator is aligned the detector registers every radiation round trip in the cavity. By fitting the peak intensities with an exponential function one may determine the resonator quality factor as: $Q = 1/t*\alpha$, where t is the cavity roundtrip time equal to $2.8\,\mathrm{ns}$ and α is exponential decay constant. From the fit shown in Fig. 4 the initial quality factor is 4.74.

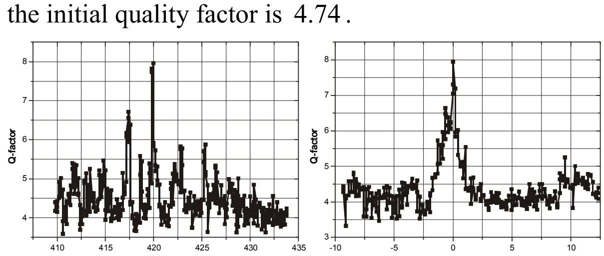

Figure 4: Cavity length and upstream mirror orientation angle scans.

This technique was found to be useful for further resonator tuning. Figure 4 represents cavity length and upstream mirror orientation angle scans versus Q-factor. One may notice that quality factor was increased up to 8.

Another important measure of the cavity state is the dependences of the resonator Q-factor versus number of bunches in a train. The decrease of Q-factor for smaller number of bunches is not clear at the moment. The analysis is still ongoing and will be discussed in a successive paper.

Figure 5: Dependences of the resonator Q-factor versus number of bunches in a train.

FUTURE PLANS AND CONCLUSION

We have successfully commissioned microwave resonator system and demonstrated a good power stacking of the Stimulated Coherent Diffraction Radiation. Further work remains to fully optimize this system and achieve higher quality factor of the cavity what will gain soft X-ray production via Thomson scattering.

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