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Bent crystals as a tool for manipulation of ultrarelativistic electron beams (12' + 3')

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Channeling and coherent interaction of charged particles in crystals are known since the 60s and used as a tool for material analysis by low-energy ion channeling and for the generation of linearly polarized γ-beams through coherent bremsstrahlung at electron accelerators, such as the MAinzer MIcrotron (MAMI) in Germany and the Jefferson Lab in USA.

If the crystal is bent, channeled particles follow the crystal bending and are steered from their initial direction. The usage of bent crystals has been deeply investigated for beam manipulation in hadron accelerators, e.g., the SPS and the LHC, where bent crystals can be exploited for beam steering in crystal-assisted collimation or extraction.

Bent crystals may found relevant application also for the manipulation of high-energy e± beams. In this case, beam deflection is accompanied by the generation of electromagnetic radiation.
Here, we present the last results on beam steering and intense e.m. radiation generation through interaction of high-energy electrons with bent crystals, by exploiting a coherent effect typical of bent crystals, i.e., the single and multiple volume reflection. Volume reflection consists
in the deflection of over-barrier particles in a bent crystal and occurs in a wide angular acceptance, which is equal to the bending angle of the crystal [1]. Multiple volume reflection occurs as a charged particle impacts on a bent crystal at several axial channeling angles with respect to a crystal axis and suffers a series of single volume reflection on several bent crystal planes intercepting the same axis [2]. A wide energy range for electrons has been selected, from sub-GeV at MAMI to hundreds-GeV at CERN. A particular attention is given to the combination of beam steering and intense e.m. radiation generation in view of possible applications, such as an intense X- or γ-ray source for the lowest energies to a crystal-based collimation at the highest ones.

A first experiment has been carried out at the CERN SPS-H4 beamline. The radiation emitted by 120 GeV/c electrons traversing a 2-mm long bent crystal under multiple volume reflection was investigated [3]. The recorded energy-loss spectrum of electrons was very intense over the full energy range up to the nominal energy of the beam and much more intense than for an amorphous medium. The radiation generation by multiple volume reflection takes place over a broad angular range of the incident beam with respect to coherent bremsstrahlung and channeling radiation in straight crystals. The large deflection angle (˜40 μrad) and wide energy lost by electrons under multiple volume reflection makes this effect suitable for application in crystal-assisted beam dump and collimation for future electron-positron colliders.

A second experiment has been carried out at the MAMI facility. We report the first observation of efficient steering of a 0.855 GeV electron beam by means of planar channeling and volume reflection in a bent silicon crystal [4]. A 30.5 μm bent Si crystal was used to steer the electron beam. This experiment opened up the way for the investigation and exploitation of coherent interactions in bent crystals in the Sub-GeV/GeV energy range accessible by many electron accelerators worldwide, e.g. SLAC, and which is interesting for innovative X- or γ-ray sources. The radiation emitted by the electrons via planar channeling and single volume reflection was also recorded [5]. The radiation spectra were much more intense than for an equivalent amorphous material, and peaked in the MeV range. In addition, the intensity of radiation accompanying volume reflection is maintained high in the whole angular acceptance, thus making this effect a good candidate for the realization of a γ-ray source with divergent electron beams.

References

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