DRWalz 3-29-01

POLARIZED PHOTON SOURCE

Coherent Bremsstrahlung Beams
From Single Crystal Diamonds Targets
For E-159, E-160 & E-161

General

- Photons radiated in ordinary Bremsstrahlung from a radiator follow a 1/k spectrum resulting in many unwanted low-energy photons and high backgrounds.
- Each photon has a polarization, but the mean polarization over all photons is zero.
- **Using a special subset of targets which are not amorphous, such as single crystals, interference effects in high-energy Bremsstrahlung with the crystal lattice enhances a subset of Bremsstrahlung processes and results in significant enhancement at well defined tunable energies or Coherent Bremsstrahlung.**

(G. Diambrini Palazzi, 1968)

- Low-Z crystals are best

  The best of the best are diamond crystals with face-centered cubic lattice.

  --Beryllium is a close 2nd

  --Silicon crystals have also been used for producing coherent γ-beams for obvious economic reasons.

Parameters Influencing Quality & Yield of Coherent γs:

- Electron Beam Energy - - the higher the better
- Small e-Beam Emittence (in one plane)
- Longitudinally Polarized e-Beam
- The Thinner the Target the Closer to Monochromatic the Photon Beam will be, -- but at the expense of yield
- **Small aperture γ-Collimator with long level arm to target and Reasonable Target Thickness will allow production of quasi-monochromatic photon beams** (essential for Experiments to succeed)
- Target Crystal Quality (Lattice Distortions, Impurities, Dislocations)
- Crystal Orientation Relative to e-Beam
- Spin Precession through A-Beam is 3.237 GeV and limits energies to multiples of this number to preserve longitudinal polarization

Historical

- 1968/69 MIT-SLAC Collaboration designed and built a GONIOMETER (L. Osborne, R. Schwitters, et.al.)

Crystal or target orientation is best done with a Goniometer or Precision Angle Positioner

- Goniometer Facility including Collimation SEM was installed in SLAC A-beam transport system to support photoproduction experiments in ESA in early and mid seventies
- 1973, Goniometer was relocated to create longer lever arm to small aperture collimator. This together with thin diamonds (0.07% X_o) allowed production of quasi-monoenergetic linearly polarized γ-beams (originally proposed by Mozley and DeWire)

Unless targets are thin, collimating effect is obscured by multiple Coulomb scattering of e^- in the target.

Primary divergence of e-beam relative to crystal axis will further impede the quality of the photon beam.

Energy spectrum of photon beam was measured by pair spectrometer.

- 1979/80, goniometer relocated to Beam Line 19 (ESB) for

Channeling Experiment D25 with Soviet Collaborators

Diamond Targets

- ♦ Want diamonds with few impurities, since exposure to the electron beam causes preferential formation of dislocations (vacancies, interstices) at these sites
- ♦ Also want crystal lattices which are not strained/warped

∴ The more perfect, the better

- ♦ Historically SLAC used natural diamonds
- ♦ They come as octahedrants from which targets are cleaved
- ♦ Diamonds are classified as Type I or Type II

Most common impurity is Nitrogen, high in Type I

Type II have little nitrogen and make up ~2% of all diamonds

∴Want the best Type II

- ♦ Supplier was diamond dealer Harry Winston & Co (NY, NY).

--The best diamonds for our purpose came from one mine, “The Mine” in South Africa

- ♦ Initial Selection was by visual inspection by diamond expert

For one SLAC order, ~3000 “stones” of 5 to 6 caret size were inspected and yielded ~8 to10 potential candidates.

- TO this state, no cost to SLAC since cleaving would also be done for jewelry.
- Pyramids were sent to NBS (Gaithersburg, MD) for further examination of crystal properties by X-ray diffraction using X-ray crystal spectrometer. Rocking curves were taken to allow comparison of diamonds with known crystals having near perfect lattices.
  α_1-α_2 = 8 to 12 arc seconds considered good. One of our targets was ~6 arc seconds, very good.

- Stones were measured "raw" and also after etching with potassium nitrate to improve surface and thus resolution of rocking curve

Yield was 3 of 8 or 10^{-3} of original lot

- Next step was cleaving of targets, 1/2 *mm* to 1-1/2 *mm* thick from pyramids at Winston & Co. and polishing down to final thickness as specified
- This was followed by a second examination at NBS to obtain final records and a baseline of targets before irradiation
- Price per "raw" carat in 1970 ~$300 (from 5 ct stone)
  Final cost of target ~5000

In case of irregularities, can always go back and take another rocking curve and compare to original

- At SLAC, targets were mounted in Be-holder followed by X-ray diffraction examination using a Laue camera to determine crystal planes/axes and shimming to achieve required parallelness with target holder frame
- Diamond targets were mechanically polished down to ~250µm thickness. Below which the risk of fracture as perceived by the vendor was greatly increased.
- SLAC developed ion beam milling process (E.L. Garwin et al.) and targets were further reduced in thickness, one of them down to ~70µm.
- Today, in 2001, in addition to natural diamond targets available from several sources, there are also manmade targets available from numerous suppliers in the US, Europe, Japan, South Africa……...

Technology to produce high quality synthetic diamond targets is rapidly advancing.

thin $8 \times 8\ mm$ targets are available with rocking curve values of 5 to 6 arc seconds.

- One of our collaborators (R. Avakian, Erivan, Armenia) is willing to supply some thin natural diamond targets.
- Another recent collaborator (F. Sellschop, Witwatersrand, Johannesburg, South Africa) is willing to supply thin synthetic diamond targets.

The collaboration will keep all options open, but diamond targets suitable for these experiments appear under control.

- ♦ Steering SEM assembly ahead of the Goniometer has two SEMs with window sizes appropriate for target size. One has small aperture to set up beam, the other to run experiment with low background while protecting Be-holder and alerting experimenter/beam operator that beam has drifted.

<u>Radiation Damage</u>

After targets have accumulated enough radiation dose to cause significant numbers of dislocations in the lattice, the diamonds color turns from clear to blue, brown and then black in region of highest dose.

Ratio of coherent/incoherent yield decreases to level where either new target is required or old target has to be annealed with UV lamp and heat.

- ♦ First anneal very successful to restore target to near original yield, single dislocations are quite mobile

Annealing after 2nd exposure not as good, since highly immobile multiple dislocations and clusters accumulate.

- ♦ Target considered to be “consumed” after ~2×10^{19} e^-.

F. Sellschop recently suggested continuous insitu annealing to never let multiple dislocations form –

Electron Beam Transport to A-beam dump

The A-beam transport was upgraded to handle 50 GeV, but the dump magnet array to dispose of the spent e^--beam after traversing the target is still limited to the original maximum of 25 GeV.

There are 4 C-type dipoles (4.72 D120C) with a 3-inch gap. They are presently equipped with 2 coils per pole, but were designed and measured with 3 coils/pole.

One proposal to increase energy capability to 50 GeV is to add a 3rd coil to each pole and also reduce total angle of bend of the array from 12° to 8°.

The latter will require installation of another beam dump above the 2.2 MW existing A-beam dump. Such a dump is on hand with a power absorption capacity of 60 to 80 kW. It can readily be connected to the existing A-beam dump radioactive water system.