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ACCELERATOR ALIGNMENT USING GAMMA RADIATION GENERATED BY ACCELERATED BEAM

It has been suggested[1] that the use of an X-ray source for purposes of alignment would eliminate the diffraction difficulties incurred with longer wavelength sources (e.g., ordinary light). This would make feasible the use of the accelerator tube itself as the "light pipe" rather than requiring an evacuated auxiliary tube of larger diameter.

The use of a conventional auxiliary X-ray source has certain disadvantages:

1. It requires additional equipment (electron source, target, power supply, etc.)
2. Photons from such a source are in the same energy range as the background radiation from induced radioactivity. As a minimum, this would probably require the use of a gated X-ray source and a gated detector.

The purpose of this note is to examine the feasibility of using gamma rays created by the electron beam in the accelerator as a source of photons for alignment purposes. In this scheme, a high Z target is placed into position along the accelerator axis by a remotely controlled actuator. For the purpose of this note it will be assumed that the target is located at the end of the first accelerator section and that the beam energy and peak beam current are 25 Mev and 100 ma, respectively. (Higher energy and/or current would be advantageous and are available if required). Retractable collimators are successively put into position at each support point as that support is adjusted to bring the accelerator into correct alignment. A scintillation detector is used at the target end of the accelerator to detect the transmitted photon beam.

At 25 Mev, a 100 ma beam striking a high X target of optimum thickness (e.g., 0.5 radiation lengths of tungsten or gold) will produce a gamma-ray beam having an intensity in the forward direction of approximately 2×10^7 R/minute at one meter.

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[1] W.K.H. Panofsky, private communication

The gamma flux equivalent to one R/min at a gamma energy of 25 Mev is approximately 3×10^6 photons/cm^2/sec. Thus, an intensity of 2×10^7 R/min is equivalent to

$$2 \times 10^7 \times 3 \times 10^6 = 6 \times 10^{13} \text{ photons/cm}^2\text{/sec at 1 meter}$$

At a distance of 10,000 ft ($\sim 3 \times 10^3$ meters) the photon flux through an area of 1 mm^2 would be

$$\frac{6 \times 10^{13}}{9 \times 10^6 \times 10^2} \cong 6.7 \times 10^4 \text{ photons/mm}^2\text{/sec}$$

Assuming a pulse length of 1 μsec, the flux per pulse is

$$\frac{6.7 \times 10^4}{10^6} = 6.7 \times 10^{-2} \text{ photons/mm}^2\text{/pulse}$$

or, at a repetition rate of 360 pulses/sec,

$$6.7 \times 10^{-2} \times 360 = 24 \text{ photons/mm}^2\text{/sec}$$

It has been assumed above that all of the photons have the full incident energy of the electrons. Actually, the Bremsstrahlung spectrum contains all photon energies from 0 up to the incident electron energy with the largest numbers at the lower energies. Since the gamma flux equivalent to one R/min increases at lower photon energies, the total number of photons/mm^2/sec may be an order of magnitude greater than the number calculated. However, since it is desirable to discriminate against the lower energy photons in order to eliminate radioactivity background, the calculated number may indeed represent the practical situation.

At the calculated flux rate, it is estimated that adjustment of a single support point in one dimension could be accomplished in roughly 2 min including the time required to transfer the alignment collimators by remote control. For two dimensions and 240 support points the total re-alignment time would thus be $\sim$ 16 hours.

The re-alignment scheme discussed here would seem to have the following advantages and disadvantages compared to the auxiliary light pipe scheme:

Advantages:

1. The principles and physical parameters can be checked out in conjunction with the Mark III or Mark IV accelerator.
2. This method does not require an auxiliary evacuated light pipe.
3. Since the photon path lies along the accelerator axis, there are no angular effects to be taken into account as with the offset light pipe.
4. Existing injection and accelerator components are utilized.

Disadvantages:

1. The use of the subject technique requires that the physics program be stopped during the time re-alignment is taking place.
2. There is not as much latitude for transverse displacement (before photon beam is lost due to striking accelerator walls) as that provided by larger (12") light pipe scheme.
3. Retractable targets are required within envelope of principal high vacuum component (accelerator).

A detailed cost analysis would be required to determine the relative cost of this scheme compared to the auxiliary light pipe method. On the one hand, the cost would be expected to be less since the 12" diameter pipe, auxiliary vacuum system, and light source are not required. On the other hand, it can be argued that the light pipe also serves in part to stiffen the support beam, a function which must be separately provided in the gamma-ray scheme. Moreover, provision of retractable targets may be more expensive in the accelerator high vacuum system than in the cruder light pipe vacuum system.