Fermilab NICADD
Photoinjector Laboratory

Technical Note 2003-03

Optical Transition Radiation at 15 MeV

Markus Hüning

Fermi National Accelerator Laboratory
Batavia, IL

March 3, 2003

Contents

List of Figures

1 Introduction

The properties of (optical/coherent) transition radiation at energies around 15 MeV will be calculated. This may later be used for the design of optical and far infrared instrumentation.

2 Ginzburg-Frank Equation

The radiation of transition radiation is described by the Ginzburg-Frank formula. In the case of metallic surfaces, which only will be considered here, it has the easy form [1]

$$\frac{d^2U}{d\omega d\Omega} = \frac{e^2}{4\pi^3\varepsilon_0 c}\frac{\beta^2\sin^2\theta}{(1-\beta^2\cos^2\theta)^2}. \tag{1}$$

The total energy per unit frequency lost by the particle at the metallic screen is found by integration of (1) over the solid angle $d\Omega = \sin\theta d\theta d\varphi$

$$\frac{dU}{d\omega} = -\frac{e^2}{4\pi^2\varepsilon_0 c}\left(2 + \frac{1+\beta^2}{\beta}\log\frac{1-\beta}{1+\beta}\right). \tag{2}$$

Note that for the detection only half of this energy is available, since the detector at maximum sees the radiation into one half space. The figure 1 shows the energy loss by a single particle. The energy has been intergrated over the visible part of the spectrum 400 nm-800 nm only. Although the formulas used here are identical with the formulas used in [1] there is a difference by a factor of two in the numerical results.

According to the above formula a particle of 15 MeV loses 0.05 eV to visible transition radiation. Out of this radiation 0.025 eV are available for diagnostics.This corresponds to a photon yield resp. quantum efficiency of 0.011.

3 Angular Distribution

The transition radiation has a very characteristic pattern. Along the principal axis there is no radiation, the intensity peaks at an angle $1/(\beta\gamma)$ with respect to this axis. The figure 2 shows the angular distribution of the transition radiation for a beam energy $\gamma = 30$. The intensity is peaked around an angle of $1/(\beta\gamma) \approx 0.033$.

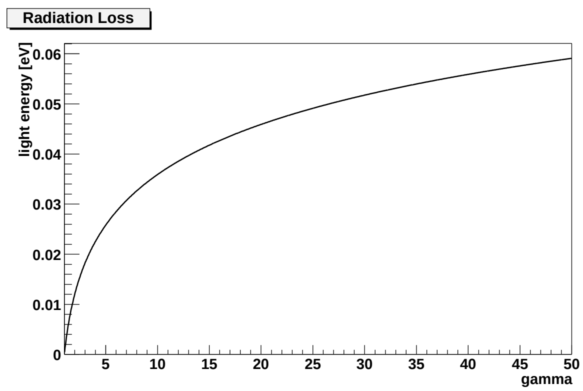

Figure 1: Energy lost by transition radiation from a single particle into the visible spectrum 400 nm-800 nm.

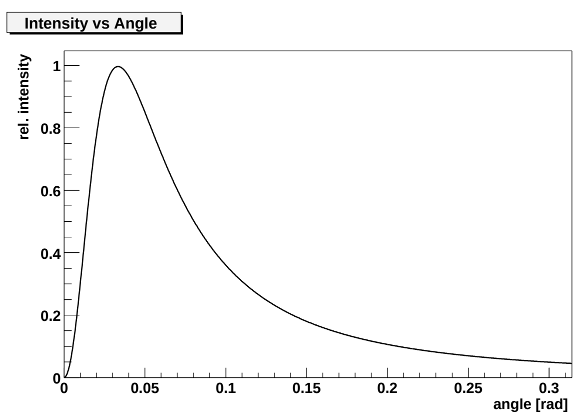

Figure 2: Angular distribution of the radiated intensity. The assumed beam γ was 30.

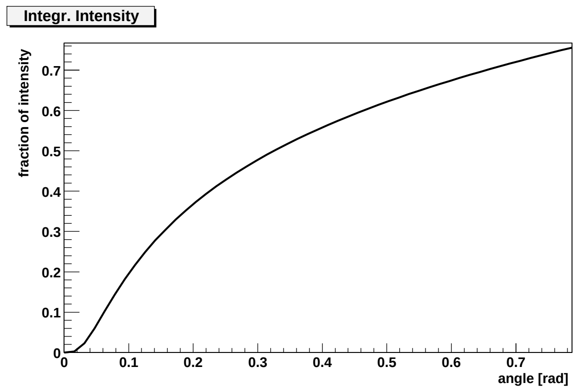

Figure 3: Integrated angular distribution of the radiated intensity. The assumed beam γ was 30. The plot has been normalized to the integral up to $\pi/2$.

The previous paragraph suggests, that most of the intensity is radiated in forward direction and little angular acceptance is required. In fact this is not the case. The figure 3 shows the intensity integrated over the angle. The integral up to $\pi/2$ has been normalized to 1. This means that already with an optical system of angular acceptance $0.325 \approx 19°$ half of the OTR energy does not hit the detector (camera). Below this acceptance the efficiency drops even faster.

References

[1] Marc A. Geitz, *Invesigation of the Transverse and Longitudinal Beam Parameters at the TESLA Test Facility Linac*, DESY-THESIS-1999-033