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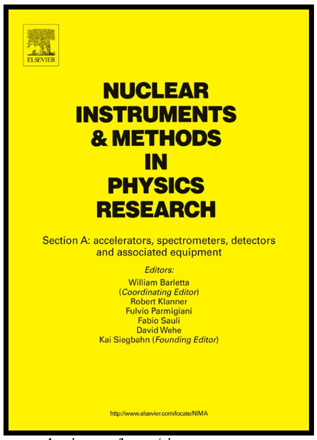

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Transverse emittance diagnostics for high brightness electron beams

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Abstract

Advanced diagnostic tools for high brightness electron beams are mandatory for the proper optimization of plasma-based accelerators. The accurate measurement of beam parameters at the exit of the plasma channel plays a crucial role in the fine tuning of the plasma accelerator. Electron beam diagnostics will be reviewed with emphasis on emittance measurement, which is particularly complex due to large energy spread and strong focusing of the emerging beams.

Keywords: diagnostics, transverse diagnostics, emittance measurements

1. Introduction

The brightness is a figure of merit largely used in the light sources, like Free Electron Lasers, but it is also fundamental in several other applications, as for instance Compton backscattering sources, beam driven plasma accelerators and THz sources. The brightness is defined as [1]

$$B_n = \frac{2I}{\pi^2 \varepsilon_{nx} \varepsilon_{ny}} \tag{1}$$

where I is the beam current, and ε_{nx}, ε_{ny} are the normalized emittance in x and y respectively. It is measured in A/m^2. Typical values of high brightness beams range between 10^{14} -10^{16} A/m^2. This definition is sometimes called 5-D brightness while when this quantity is divided by the energy spread it is called 6-D Brightness, see for instance [2].

Increasing current or reducing emittance or having together these effects are different ways to produce high brightness beams. However different diagnostics apply in every different conditions. For instance few picoseconds bunch length are highly demanding for longitudinal time resolution, while high charge beams usually require not intercepting diagnostics. So high brightness diagnostics refers to a very wide spectrum of different conditions.

Plasma based accelerators have demonstrated the ability of delivering high energy beams in a very compact dimensions. There are several challenges related with these new techniques and one among the other is the possibility to produce high brightness beams. We focus our attention only on the plasma accelerated beams.

In order to measure the longitudinal and transverse properties of such beams new diagnostics techniques must be used, adapting existing methods or inventing new ones. We concentrate in this paper only on transverse measurements and in particular on emittance measurements. A more complete, albeit not exhaustive, review of both longitudinal and transverse diagnostics can be found in [3].

The main issues for this diagnostics are the shot to shot instabilities and the large energy spread. So mainly only the single shot measurements are eligible for such a task.

2. Single shot incoherent OTR based emittance measurements

When the space charge contribution is negligible the quadrupole scan [4] is the most used technique to measure the emittance. It is based on the measurement of the beam transverse spot changing the current in one or more quadrupoles. But it is a multi shot measurement and because it uses magnetic lenses, it is very sensitive to energy spread [5]. Unfortunately up to now there are not reliable and well established single shot measurements of transverse emittance, while several experiments have been already carried out, as reported in [3].

Optical Transition Radiation (OTR) is emitted when a charged particle crosses the boundary between two media with different index of refraction. It is well known since many years [6], but only in the '90s received attention as powerful diagnostics tool. We focus here on the incoherent part of the radiation emitted at wavelength shorter than the bunch length. It happens often in the visible range.

While collecting and imaging the emitted radiation is a simple system to measure the beam charge transverse distribution and also its dimensions, there are more information hidden in the angular distribution of the radiation: the energy and the angular spread of the beam that produced it.

A simple setup is shown in Fig.1 where the radiation, coming from a metallic screen (often a silicon aluminated plate) placed

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