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A Low-Cost Beam Profiler Based On Cerium-Doped Silica Fibers

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Abstract

A beam profiler called the Universal Beam Monitor (UniBEaM) has been developed by D-Pace Inc. (Canada) and the Albert Einstein Center for Fundamental Physics, Laboratory for High Energy Physics, University of Bern (Switzerland). The device is based on passing 100 to 600 micron cerium-doped optical fibers through a particle beam. Visible scintillation light from the sensor fibers is transmitted over distances of tens of meters to the light sensors with minimal signal loss and no susceptibility to electromagnetic fields. The probe has an insertion length of only 70mm. The software plots the beam intensity distribution in the horizontal and vertical planes, and calculates the beam location and integrated profile area, which correlates well with total beam current. UniBEaM has a large dynamic range, operating with beam currents of ~pA to mA, and a large range of particle kinetic energies of ~keV to GeV, depending on the absorbed power density. Test data are presented for H^- beams at 25keV for 500µA, and H^+ beams at 18MeV for 50pA to 10µA. Maximum absorbed power density of the optical fiber before thermal damage is discussed in relation to dE/dx energy deposition as a function of particle type and kinetic energy. UniBEaM is well suited for a wide variety of beamlines including discovery science applications, radio-pharmaceutical production, hadron therapy, industrial ion beam applications including ion implantation, industrial electron beams, and ion source testing.

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1. Introduction

For beamline operators, beam profilers are crucial for verifying beam size and position, as well as the beam intensity distribution shape. Beam profilers allow operators to observe the effects of focusing and steering in real time, and to observe the real-life effects of vacuum quality, space charge and second-order effects causing beam halo. However, the use of beam profilers with industrial accelerator beamlines is often limited or non-existent despite the advantages they provide, often because of budget and space limitations, as noted by Dehnel et al. (2013).

A beam profiler based on doped SiO_2 optical fibers was designed and tested at the Albert Einstein Center for Fundamental Physics (AEC), Laboratory for High Energy Physics (LHEP), University of Bern, Switzerland. This beam profiler, called the Universal Beam Monitor (UniBEaM™), was conceived to meet the requirements for a simple, robust, compact, inexpensive and continuous-monitoring beam profiler. UniBEaM has a large dynamic range, operating with beam currents of ~pA to mA, and a large range of particle kinetic energies of ~keV to GeV, depending on the absorbed power density. Braccini et al. (2012), and Auger et al. (2016) described the use of UniBEaM on their 2MeV and 18MeV proton accelerators. UniBEaM was licensed and commercialized by D-Pace Inc. Canada. This paper describes the commercial UniBEaM design and provides example measurements.

2. UniBEaM System Description

UniBEaM is an alternative to conventional wire scanners. Unlike available commercial wire scanners in the same price range, UniBEaM is superior for measuring a wide range of beam currents and particle kinetic energies, and is particularly well suited to measuring low beam currents. The UniBEaM signal is optical rather than electrical, making small signals insusceptible to interference. UniBEaM also provides control of the speed and position of the fiber, so that the user has flexibility to control integration time for low current beams and to synchronize fiber positioning with pulsed beams. Rotating helical wire scanners do not allow this. Dual orthogonal fibers also occupy less space along the beam axis than rotating helical wire scanners.

Each UniBEaM probe has two sensing fibers; one for X-profiles and one for Y-profiles (see Fig. 1 & Fig. 2). The sensor fibers are moved through the beam by stepper motor actuators. Home switches ensure accurate fiber positioning. There are no electronic components in the probe, making the probe radiation resistant. Two ports in each probe provide access to replace the fibers. Replacement sensor fibers are provided in protective cartridges which also serve as the installation tools. Fiber replacement takes about two minutes following vacuum venting. UniBEaM is an in-line device – it does not require a separate vacuum box or beam-pipe cross. KF and CF flanges options are available. With KF bulkhead clamps, the device has an insertion length of only 70mm.

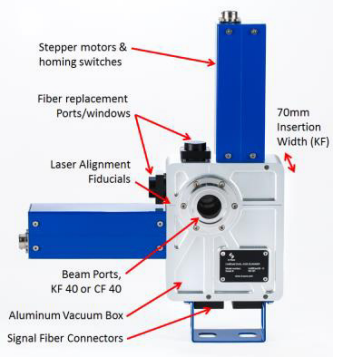

Fig. 1. D-Pace's commercial UniBEaM dual axis probe

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