

NEW COMPACT DESIGN OF A THREE-DIMENSIONAL IONIZATION PROFILE MONITOR (IPM)

Heiko Breede*, Hans-Jürgen Grabosch, Lap Van Vu, Martin Sachwitz
Deutsches Elektronen Synchrotron, Platanenallee 6, 15738 Zeuthen, Germany

Abstract

FLASH at DESY in Hamburg is a linear accelerator, which uses superconducting technology to produce soft x-ray laser light ranging from 4.1 to 45 nm. To ensure the operation stability of FLASH, monitoring of the beam is mandatory. Two Ionization Profile Monitors (IPM) detect the lateral x and y position changes. The functional principle of the IPM is based on the detection of particles, generated by interaction of the beam with the residual gas in the beam line. The newly designed IPM enables the combined determination of the horizontal and vertical position as well as the profile. This is made possible by a compact monitor, consisting of a cage in a vacuum chamber, two micro-channel plates (MCP) and two repeller plates with toggled electric fields at the opposite sides of the MCPs. The particles created by the FEL beam, drift in a homogenous electrical field towards the respective MCP, which produces an image of the beam profile on an attached phosphor screen. A camera for each MCP is used for evaluation. This indirect detection scheme operates over a wide dynamic range and allows the detection of the center of gravity and the shape of the beam. The final design is presented.

INTRODUCTION

To ensure a smooth operation of the free electron laser FLASH at DESY Hamburg, numerous detectors for the precise measurement of the electron and laser beam are necessary. The great advantage of the here described Ionization Profile Monitor (IPM) is an undisturbed determination of the position and intensity distribution of the laser beam.

MEASURING PRINCIPLE OF AN IONIZING PROJECTION MONITOR (IPM)

The FLASH laser beam with a variable wavelength from 4.1 to 45 nm is located in an Ultra High Vacuum (UHV) beam pipe. Despite the vacuum a certain amount of residual gases still exist. If the laser beam hits a residual gas atom, it becomes ionized and charged electrons and ions are created. By means of a homogeneous electric field, these electrons and ions can be deflected in a rectilinear way towards the micro-channel plate (MCP). Here, the impacting particles create an avalanche of secondary electrons in the micro tubes of the MCP and are being visualized on the phosphor-screen. These results in an image of the intensity-dependent laser

beam profile (see Figure 1).

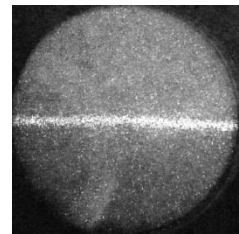


Figure 1. Image of the FLASH laser beam [1] [5].

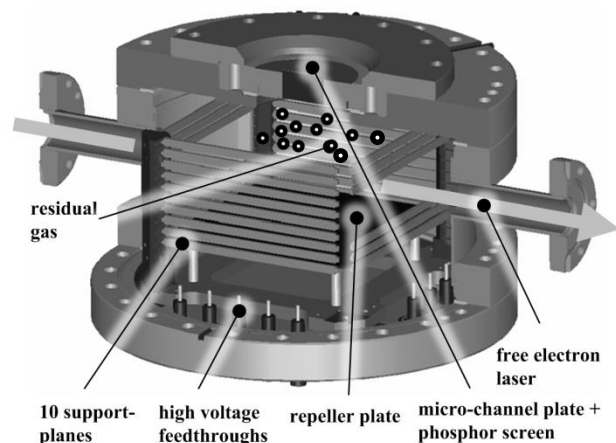


Figure 2. Conventional Set Up [5]

CONVENTIONAL SET UP

Figure 2 shows an IPM module for the laser beam position measurement as implemented in FLASH [1] [5]. Problems and disadvantages of this design are the following:

- The large size of the monitor (approx. 400 mm x 300 mm x 200 mm) results in an insufficient homogeneity of the electrical field applied. Therefore the exact path of the electrons or ions from the origin of creation to the MCP is unknown and the spatial resolution is in the order of about ± 50 microns.
- The size makes the IPM harder to manufacture and more expensive due to the high number of high voltage feedthroughs.
- To detect the horizontal and vertical parameters of the laser beam (3D) two consecutive detectors have

to be implemented with perpendicular orientation to each other demanding large space.

- To take a look at the single bunches rather than just examining the whole train, the IPM needs a time resolution of at least 100 ns, a value the conventional set is not capable of achieving.

A NEW DESIGN OF THE IONIZATION PROFILE MONITOR

In order to tackle the challenges described above the following design is proposed:

- Unification of the separate horizontal and vertical monitors with an alternating homogeneous electric field.
- A special cage protects the area of interest from electrical stray fields to ensure an optimal homogenous electric field.
- Decreasing the size of the device to 203 mm x 218 mm x 246 mm while at the same time reducing the applied electrical voltage with the appropriate low cost feedthroughs.
- With the Finite Element Method (FEM) a comparison of different residual gas particles is performed concerning their trajectories in the electric field.
- This procedure offers an optimization of the design by simulating the trajectory of the particles in the electrical field with the deflection caused by the inhomogeneity of the field. Varying the CAD monitor model helps finding out the best possible determination of the laser beam position.

Following the principles described above in figure 3 the resulting new design of a 3D detector is presented. The inner cage with a measure of 100 mm x 100 mm x 100 mm consists of equally sized pads, plates and two 28 mm diameter holes for the passage of the beam. Figure 3 shows that 30 different electrical potentials are needed to achieve a homogeneous field.

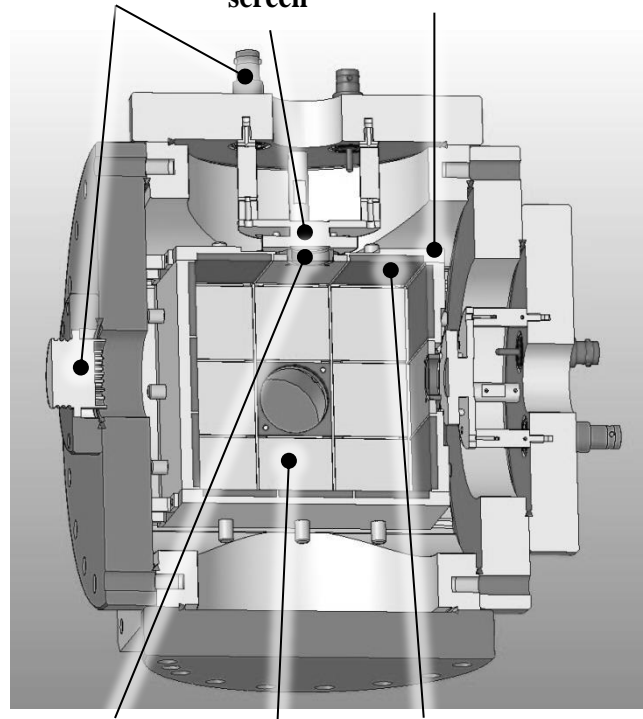
Device Specifications

The following parts were chosen:

- 1x stainless steel block with measures 140 mm x 203 mm x 203 mm
- 2x reducing flange 160 to 100
- 2x special reducing flange 100 to 40 with electrical feedthroughs
 - SPE-10046425-10 [6]
- 1x CF160 flange
- 1x CA100 flange
- 2x special coated sight glass
 - VPCF40DUVQ-L-BBAR2 [6]
 - Fused Silicia with anti-reflective coating
 - transmission range: 400 nm - 800 nm

- 1x 41-time electrical feedthroughs with plugs and cables
 - W-MPC2-41-DE-CE-SSG [6]
- 2x micro-channel-plate and P47 phosphor screen assembly by HAMAMATSU
 - F2222-27P227 [4]
- 2x grid bonded in a ring washer by Precision Eforming
 - MN49 bonded to 20mm SS Frame [7]
- potential support plates and pads consisting of stainless steel
- an inner retainer of the cage consisting of MACOR by MCI UG [9]
- a pulse generator for generating an alternating orthogonal electrical field
 - Matrixpuls 1x21 by GBS ELEKTRONIK GmbH
 - able to grant 100 kHz [8]
- Cameras, which could be chosen by user, but should have a fast shutter time (for example 100 ns) and a high frame rate to achieve a bunch resolution

electrical feed-throughs **micro-channel plate & phosphor-screen** **ceramic isolator (spacer & case)**



potential support grid **potential support pad** **potential support plate**

Figure 3. Design of the 3D-IPM [3]

FEM ANALYSIS

To analyse the homogeneity of the electric field and to determine the trajectory of different particles obtained with the design described above, a FEM analysis was carried out using ANSYS 14 modules workbench [2] and classic [2]. In the simulations different variations and possible future developments of the design were included directly from the CAD-model.

Potential ratios

Simulation studies performed with the workbench module package proved the potential ratios, as can be seen in figure 4, to be optimal for a homogeneous electric field and hence for a straight flight of particles. Since the MCP has a diameter of merely 20 mm, only in the marked "area of interest" the electric field must be homogeneous. Also, the expected beam variation in X or Y is below ± 5 mm. Homogeneity in a larger space does not result in a higher spatial resolution.

The electrically conductive potential supporting points are assumed as being an ideal conductor with equal potential at any point. The permittivity of the ceramic was assigned to $\epsilon = 6$ and of the vacuum to $\epsilon = 1$.

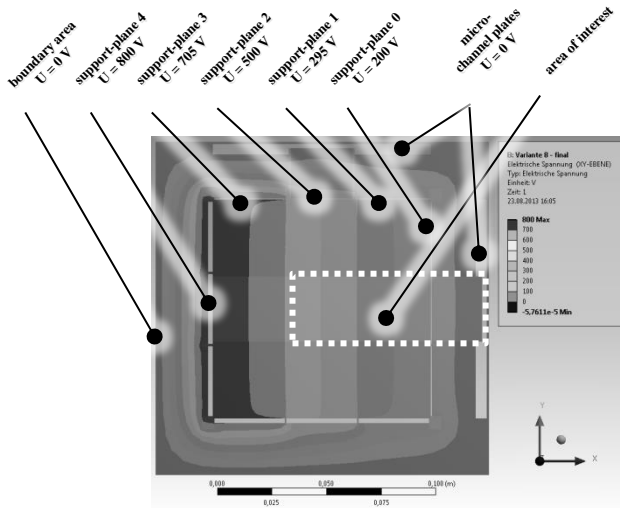


Figure 4. Equipotential lines of the electrical field. [2]

CONCLUSION

The first prototype of a 3D-IPM is currently under construction and will be completed and tested in 2013. Before any test with a toggling electrical field, there will be tests with a rigid field. First practice tests are planned in 2014 at FLASH in DESY Hamburg site.

REFERENCES

- [1] M. Sachwitz, A. Hofmann, S. Pauliuk, K. Tiedtke, H. Wabnitz, "Proc. of EPAC08", 1266-1268 (2008).
- [2] ANSYS 14 Workbench und Classic, www.ansys.de.
- [3] Solid Edge ST3,
- [4] Phosphor-screen P47, Hamamatsu Photonics Company, www.hamamatsu.com.
- [5] Miesner, J., Sachwitz, M., Markert, M., Sternberger, R., Tiedtke, K., Hofmann, A., „An Ionization Profile Monitor for the determination of the FLASH photon beam parameter“, Nucl. Instr. and Meth. A 635, S104-S107 (2011).
- [6] VACOM Vakuum Komponenten & Messtechnik GmbH, www.vacom.de.
- [7] Precision Eforming LLC, <http://www.precisionforming.com>
- [8] GBS ELEKTRONIK GmbH, <http://www.gbs-elektronik.de/>
- [9] MCI UG, <http://www.mc-i.de>