**AGOR-Facilty for IRradiation of Materials**

*(technical review)*

**AGOR-FIRM BEAM LINE SET-UP**

*"Beam side view" of the FIRM set-up*

Overview of the DUT (device under test) position: XY-table (left) with attached reference frame and Multi-Leaf Degrader (right) mounted on breadboard construction table. In the background an XY-laser from the 3D-alignmensystem (in the orange frame) can be seen. In this view, the beam enters from the right side.
Schematic view of the KVI-Experimental area. The multi-user facility FIRM and the “B-lab”, available for measurements and storage of irradiated materials and equipment, are located on the right side.
In the picture above you find a view of the AGOR-FIRM Beam Line set-up (beam entering from the bottom). The beam line is mounted on 3 separate structures, each with a breadboard mounting table. The dimensions of each table is 900x1800mm with a 25mm pitch M6 hole pattern. The items, mentioned in the drawing, will be declared in the next paragraphs.
In the beam line, 2 harps are mounted. They consist of 48 gold plated 50-micron tungsten wires each (24 horizontal and 24 vertical) with a spacing of 1mm. For signal amplification in air, high voltage screens are mounted on the entrance and exit window (not mounted in this example). The first harp (HXH3) is located at the waist of the beam. Typically, the beam size at this position is 2-3mm FWHM. The second harp (HXH4) is located 1250mm downstream. Since there are no focusing elements between them, xy-position, diverging and steering of the beam are easy to measure, giving a first order indication of the behavior of the beam at the DUT position.

DOUBLE SCATTER SYSTEM

Around the harp HXH3, near the waist of the beam, a double scatter system is mounted. Depending on the primary beam energy, it consists of a homogeneous scatter foil of 1.16 or 1.44 mm lead and a inhomogeneous shaped 0.9mm tungsten foil. For protons, at the DUT, a maximum beam size of approximately 140mm diameter can be reached.

Field flatness/ homogeneity at 70mm: +/-3%
120mm: +/-10%
140mm: +/-25%

For 90MeV/A carbon ions, a 30mm field is available with a homogeneity of +/- 1% with a single homogeneous scatter foil.

Dose distribution of a 190MeV proton beam in a LaneX screen. Used field shaping collimator: 80mm. Typical penumbra: 1-2mm
IONIZATION CHAMBERS, CHOPPER AND CONTROL

In the beam line, 2 non-interceptive ionization chambers are available. They have a multi-layer configuration where a “signal plate” is always surrounded by 2 high-voltage plates. The high-voltage plates amplify the signal of the passing particles, thus generating a signal that is linear with respect to the amount of passing particles.

BIM1 consists of one signal plate covering the whole field; one plate that cover a top- and bottom field and a 3rd plate that covers a left/right field. With this configuration it is possible to control the beam-current as well as its position with respect to the beam axis. It is used as a control monitor for BIM2.

BIM2 (counterbim): consists of 2 signal plates, both covering the whole beam field. The BIM readout directly steers a chopper signal via a real time control system, switching the beam on or off within a few milliseconds.

The signal is used for an absolute calibrated dose measurement (Gy/sec) during the irradiations. It also controls the total dose (Gy) given to an irradiated sample.

Both ionization chambers, BIM1 and BIM2 can be calibrated by the use of Unidos calibrated “Farmer- and Markus chamber equipment in combination with a PTW electrometer, placed at the position of the DUT.

Calibration of the BIMs to the absolute amount of passing particles (flux: particles/cm^2/sec) is also possible by placing a small detector at the position of the DUT. In this way the total amount of passing particles (fluence: particles/cm^2) can be controlled.

All BIMs are read-out via the AGOR-FIRM-Control system and logged during the irradiations.

DOSIMETRY CAMERA SYSTEM

To measure the dose-distribution (field-flatness) at the position of the DUT, a dosimetry camera is available. The camera is a “dark-current” CCD camera with the possibility to make long shutter time (BULB) images. The camera is viewing the DUT position via a mirror from the backside. During the measurement a scintillating Kodak-LaneX screen is placed at the position of the DUT. In a measurement of 20 seconds, a calibrated amount of dose is given to the screen. All scintillated light is gathered by the camera. The image is analyzed by MatLab software.
RANGE TELESCOPE

To determine the primary beam energy, a range telescope is available (see picture on page 5). It consists of a stack of very thin aluminum plates, with capton isolation in between. It can be placed directly in the beam. The energy of the beam is determined by the reached depth in the aluminum plates. The device has a real time read-out and a resolution of approximately 1 MeV.

DUAL-POSITION FIELD COLLIMATOR

At 150mm in front of the DUT-position, a collimator holder is positioned. The holder can keep 2 field-shaping collimator blocks with a maximum diameter of 140mm. During the irradiation the position of the holder can be changed, giving the opportunity to irradiate your sample with 2 different fields without entering the area.

The field collimators are the last collimators in the beam line. They determine the shape of the beam on your sample. Typically, the collimator is a circular brass block (diameter: 149.2mm) with an arbitrary opening where the beam passes. The thickness of the blocks is 45mm, necessary to stop 190MeV protons. A number of standard field shapes are available, but for special irradiations, “strange” shapes can be designed on demand and can be machined by the wire erosion (Electrical Discharge Machining) technique. Without degrader materials a fall-off (penumbra) on the collimator edges of 100->0% in 1 mm can be reached.

Standard available collimator sizes are:

Circular (diameter):  5  30  50  70  80  100 130 mm
Square/rectangular:  10x1  10x2  10x3  10x4  10x7.5  10x12  10x16  10x19 mm
                      20x20  30x30 mm
                      100x2  100x4  100x8  100x20  100x40  100x50  100x100 mm
Off-line mounting of a multi-sample holder in the XY-table. On the right side, the dual position field collimator holder can be seen. Currently a 30mm carbon collimator with degrader material is mounted. On the foreground, a “peddle” detector, used for calibration purposes.

**MULTI-LEAF ENERGY DEGRADER**

The multi-leaf degrader (see also picture on page 1) consists of a stack of aluminum plates that can be “shifted” in or out the beam. The plates have a different thicknesses and can be remotely operated. By changing the total thickness of the stack, the energy of the beam can be degraded from its primary value to 0 MeV in binary steps of 0.5mm aluminum.

The total amount of plates: 9
Thickness of the plates: 0.5 1 2 4 8 16 32 32 32 mm.

The total thickness of 127.5mm is sufficient to stop a 190MeV proton beam. On demand, thinner foils can be added on an additional stack holder to make an even finer energy change possible. Degrading the beam influences the beam quality. Scattering of the beam will increase and also the fall-off (penumbra) and field flatness at the field collimator and DUT position will be worse.

Multi-Leaf Degrader: on the photo, the degrader is adjusted to 16.5mm using a 16mm and a 0.5mm aluminium plate.
An XY-table (see picture on page 1) is available for fast mounting of samples that have to be irradiated. The range of the table is $X$(horizontal)$=600\text{mm}$ and $Y$(vertical)$=300\text{mm}$. Maximum load of the samples on the XY-table is approx. 5kg. The reference plate of the XY-table is aligned with respect to the bolt raster of the breadboard support structure of the beam line below. This means that we know where the center of beam is: in the center of the raster plate. From there, we have the possibility to move the raster plate 150mm in all directions. The XY-table can be placed on an arbitrary position in the beam line on the breadboards below without further alignment.

**Reference frame** (green in above drawing): This is a fixed part of the XY-table. It has an opening of 300x300mm. The center of the beam can reach all corners of the attached mounting window. Any part can be attached on the bolt-holes with a pitch of 10mm all around the plate. Detailed information can be found in the next picture. NB: the 5.1mm holes are not threaded.
**Mounting plate:** We have a number of these 0.5 and 1.0 mm thick aluminum plates available. They can be mounted on the ‘reference plate’ without bolts by slot-holes. To attach your samples on these plates, holes can be drilled on any demanded position in these plates or be simply taped on the surface.

If samples are too large for the XY-table, they could be mounted directly on the table surface. On demand, additional information about alignment and mounting is available. There is also a possibility for mounting a single rotating target, giving you the opportunity to rotate your sample for a uniform irradiation.

**3D-LASER ALIGNMENT SYSTEM**

The alignment system consists of 3 positioning-line/cross lasers on the walls and on the ceiling that determine the isocenter of the beam with respect to the DUT. In addition there is a possibility to mount a fourth laser on the axis of the beam, pointing directly towards the sample (simulated beam). Before the start of irradiations we need to determine the position of the samples with respect to the center of the plate. For samples that have to be mounted far from the DUT position, a portable line laser systems (horizontal/vertical line) are available.

**ENERGY MODULATING WHEELS**

For Bragg-peak irradiations an energy modulating wheels are available for carbon and for protons of a fixed starting energy. With the modulator wheels a Spread Out Bragg Peak (SOBP) can be created from a single energy.
CABLING

Distances (for cabling purposes) between:

- DUT- patch panel and B-Lab (to be found on the layout on page 2): 40 meters
- DUT- patch panel and Counting room patch panel: 65 meters
- DUT- table and working table in Counting room: 67.5 meters

Several cables of different types (f.i. BNC, SHV, RS232 and Cat5/Ethernet) are available between these area's.
- From the DUT table to the outside world (basement), a minimal cable length of 15 meters is required. Additional cables can be produced on request by our electronics shop.
- For gasses, an exhaust hose is available to the outside world.
- B-Lab and counting room are accessible during the irradiations. The basement is not accessible during irradiations.

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