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EURO-LABS

EUROpean Laboratories for Accelerator Based Science

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MILESTONE REPORT

ELECTROSTATIC MICROPROBE QUADRUPOLE QUADRUPLET LENS ASSEMBLY INSTALLED AND TESTED

MILESTONE: MS26

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Abstract:

Within the scope of work-package 4.4, subtask 4.4.4 aims to provide an electrostatic beam focusing lens system with the ion beam scanner for the RBI double microbeam end station installed at the RBI Tandem Accelerator Facility. This document describes the activities towards getting this service improvement ready for the users.

For more information on EURO-LABS, its partners and contributors please see https://web.infn.it/EURO-LABS/

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	Name	Partner	Date
Authored by	G. Provatas, M. Jaksic, S. Fazinic	RBI	11/12/23
Edited by	G. Provatas, M. Jaksic, S. Fazinic	RBI	11/12/23
Reviewed by	M. Mikuž [Task coordinator] M. Mikuž [WP coordinator]	JSI JSI	16/12/23
Approved by	Navin Alahari [Scientific coordinator]	GANIL	19/12/23

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Executive summary

Within the scope of work-package 4.4, subtask 4.4.4 aims to provide an electrostatic beam focusing lens system with the ion beam scanner for the RBI double microbeam end station installed at the RBI Tandem Accelerator Facility. The Electrostatic Lens Assembly, purchased just before the project start, has been installed, aligned and tested. Initial tests were carried out by means of local control, using NIM Power Supply units. The latter have been replaced with 4 GlassMan Power Supplies which are now remotely controlled within EPICS. The ion beam resolution was initially tested by means of sample scanning in front of a fixed ion beam. With the proton beam, the obtained map resolution was estimated to 7.4 µm/pixel for the low beam current. As alternative to scanning the sample in front of the fixed ion beam, an electrostatic ion beam scanner was developed and installed. In this case, sample is held in a fixed position while the ion beam is scanned across the sample. The electrostatic scanner consists of 4 parallel copper plates mounted on a cylinder positioned after the electrostatic focusing quadrupoles. The scanner is connected to two KEPCO bipolar power supplies. Scanning is controlled by the local data acquisition software SPECTOR. Tests with the proton beam have shown that the beam spot was about 7 µm in diameter for low current mode and 36 µm for high current mode accordingly. Additional tests have been carried out in high-current mode with a 12.8 MeV C^{4+} as well as a 12 MeV Si^{4+} beam. From these tests the beam spot size was estimated to be ~22 µm along the vertical and 40 µm along the horizontal axis. With the activities performed and reported herein, milestone M26 has been achieved.

1. INTRODUCTION

RBI Tandem accelerator facility (RBI-AF) is used for experiments in nuclear physics and applications. RBI-AF is equipped with a 1 MV Tandetron and a 6 MV EN Tandem accelerators and 9 end-stations (*Fig.1*), including two ion microprobe stations (E3, E9).

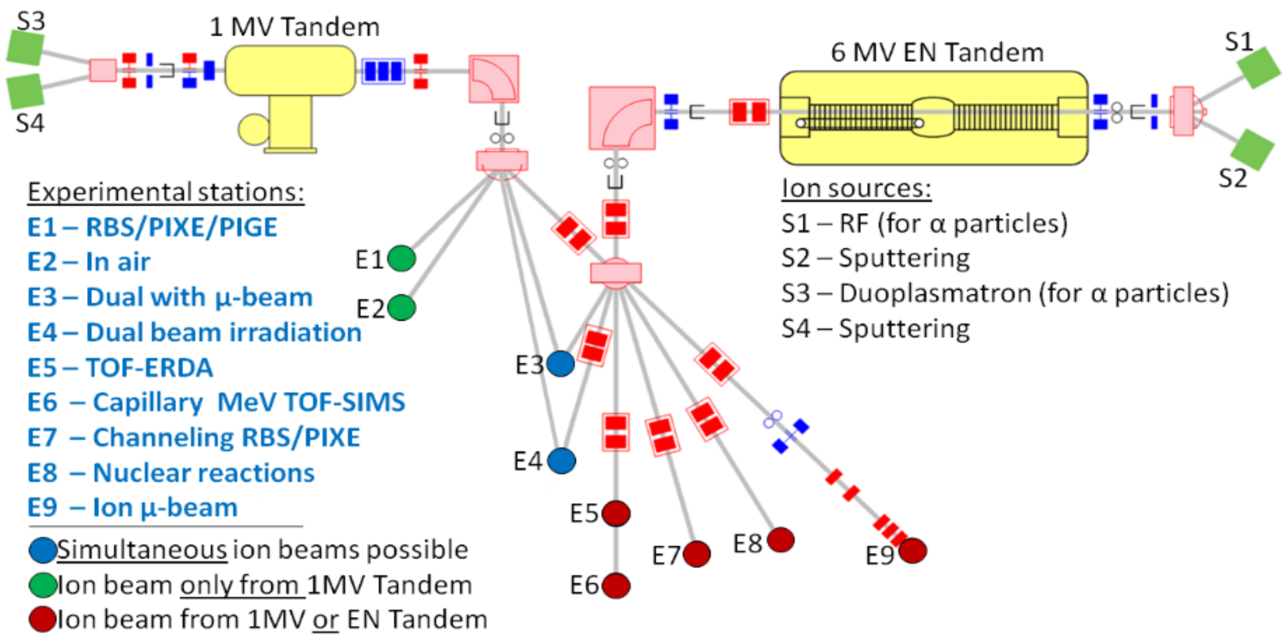

Fig. 1. The RBI Tandem Accelerator Facility (RBI-AF).

Both ion microbeam stations have multifunctional capabilities, including ion irradiations at a microscopic scale and the use of ion microbeams as a probe for detector characterization studies.

These end-stations are key instruments for detector characterization at a microscopic scale. RBI-AF has been regularly used by many international research groups for various applications. Within EURO-LABS WP4, subtask T4.4.2 RBI-AF provides transnational access for detector characterization.

The new ion microbeam line (E3) comprises two separate beamlines, one connected to the 1 MV Tandem accelerator, and the other one to the 6 MV EN Tandem accelerator. Therefore, sequential or even simultaneous irradiations from both accelerators are possible. However, at the start of the EURO-LABS project the second beam line was not equipped with the ion beam focusing capability (ion beams could only be collimated). Within the task T4.4. 'Service improvements' of the EURO-LABS project, it is aimed to introduce ion beam focusing capability to enable microscale irradiations from both beam lines at the new ion microprobe end-station.

2. DETECTOR CHARACTERIZATION AT RBI-AF

RBI-AF has been regularly used by many international research groups for detector characterization, mainly by exploiting the IBIC (Ion Beam Induced Charge) technique [1,2] and irradiation by MeV ions for radiation hardness studies [3].

In vacuum and in-air IBIC imaging of detector charge collection properties using protons of up to 10 MeV with 1 μm resolution and heavier ions on demand, and/or time resolved IBIC (TRIBIC) can be performed at one of the two ion microbeam end-stations (*Fig.1*, E3 and E9). The 'old' ion micro-beam station (E9) has been in use for about three decades, while the 'new' one (E3) has been under development.

Regarding radiation hardness studies, this usually includes real-time controlled damaging of small detector areas using protons or heavier ions, including simultaneous or subsequent ion beam analysis. In addition to the two ion microprobe end-stations (E3, E9), the remaining end stations are also on disposal for such studies, depending on the actual objectives of the proposed work.

Dual beam irradiation (E4, DiFU) end-station [4] can be used for irradiation of samples with an area up to 2x2 cm^2. Samples can be irradiated at room temperature or up to 600 C. Time-of-Flight Elastic Recoil Analysis end-station (E5, ToF ERDA) is used for thin film analysis [5]. The ion channelling end-station (E7) is regularly used for irradiation and analysis of crystalline materials [6].

3. SUB-TASK 4.4.4. SERVICE IMPROVEMENTS AT RBI-AF

3.1. OBJECTIVES OF SUBTASK 4.4.4.

The left side of Figure 2 shows the 'new' dual-microbeam end-station. On the right, a schematic view is displayed, while the left photo depicts the actual installation. As can be seen, it is connected to both accelerators via two beamlines.

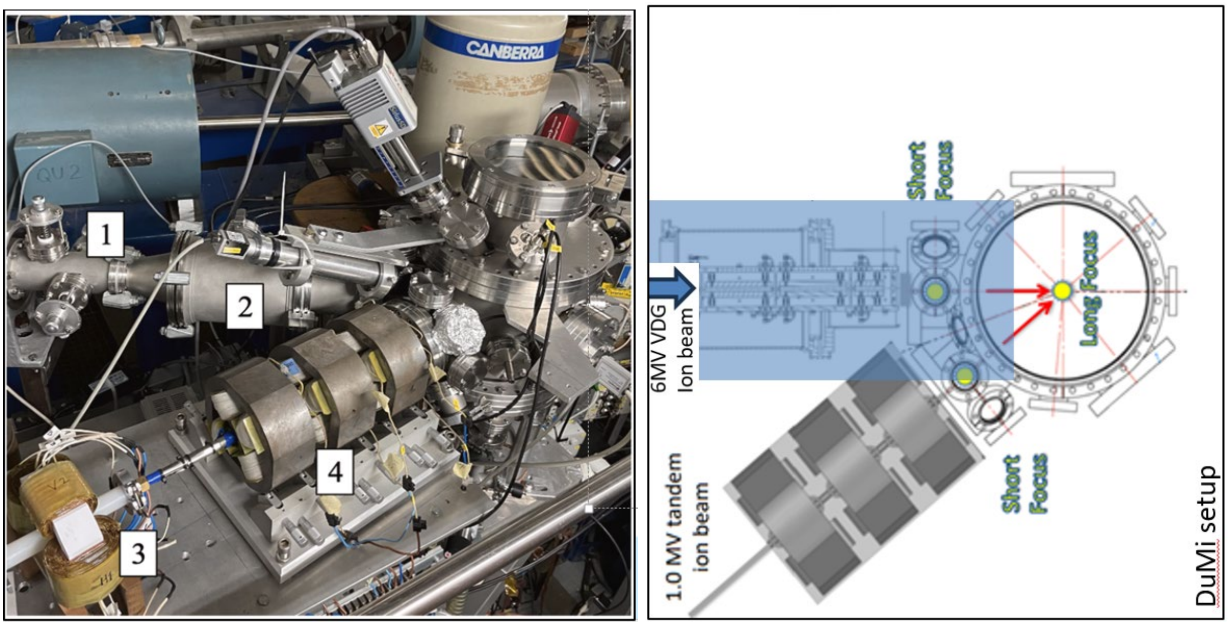

Fig. 2. Present view of the 'New' dual-microbeam station (E3). Left: (1) 6 MV EN tandem beam line; (2) Electrostatic focusing lens system; (3) 1.0 MV tandem beam line; (4) Magnetic quadrupole focusing lens system. Right: Schematic view of the dual-microbeam end station.

At the start of the EURO-LABS project the beamline connected to the 6 MV EN tandem was not equipped with any ion beam focusing capability (ion beams could only be collimated) while the beamline connected to the 1 MV tandem was equipped with a locally designed and produced magnetic quadrupole lens system. It was decided to add the ion beam focusing capability to the 6 MV EN tandem beamline, including controlled ion beam scanning over the samples. This is the main objective of subtask 4.4.4. within WP4 Task 4.4. 'Service improvements'. As the result of this service improvement, experimental capabilities of the 'new' ion microbeam end-station will be considerably enhanced.

3.2. SIGNIFICANT ACTIVITIES AND ACHIEVEMENTS

The Electrostatic Lens Assembly [7], purchased just before the project start, has been installed, aligned and initial tests were performed. These tests were carried out by means of local control, using NIM Power Supply units. The latter have been replaced with 4 GlassMan Power Supplies [8] which are now remotely controlled within EPICS [9]. In Figure 3, the focusing setup is shown along with the control user interface. At the bottom right the ionoluminescence of the 12 MeV Si^{4+} microbeam on a CsI crystal as observed by the short view video camera is shown.

The ion beam resolution was initially tested by means of sample scanning. A Cu mesh was mounted on the motorized computer-controlled piezo-stage sample holder and scanned in front of the ion beam. Then the Scanning Transmission Ion Microscopy (STIM) technique was used in on/off-axis STIM modes to obtain the ion transmitted intensity maps shown are shown on the right side of Figure 4, while the photograph on left side show the setup. With the proton beam, the map resolution was estimated to 7.4 µm/pixel for the low beam current.

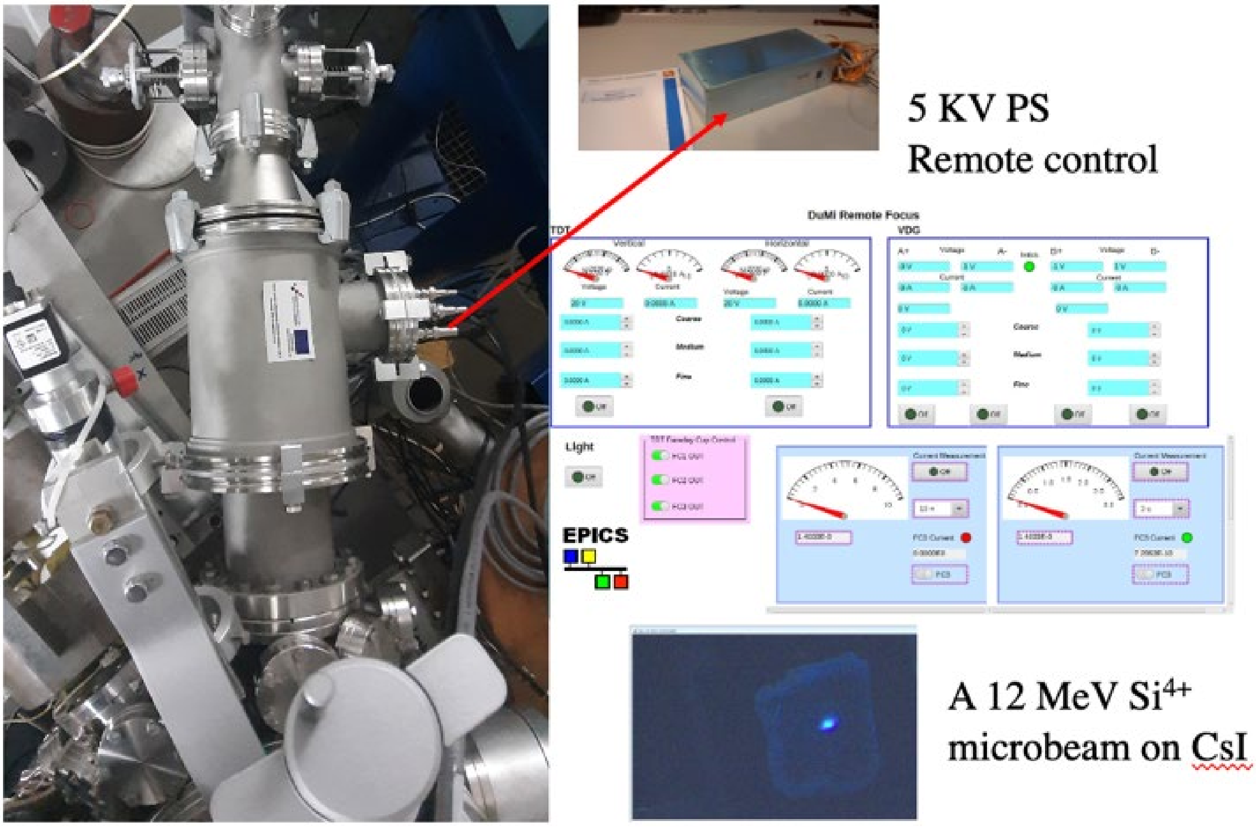

Fig. 3: The Electrostatic Lens Setup installed at the E3(DuMi) end-station.

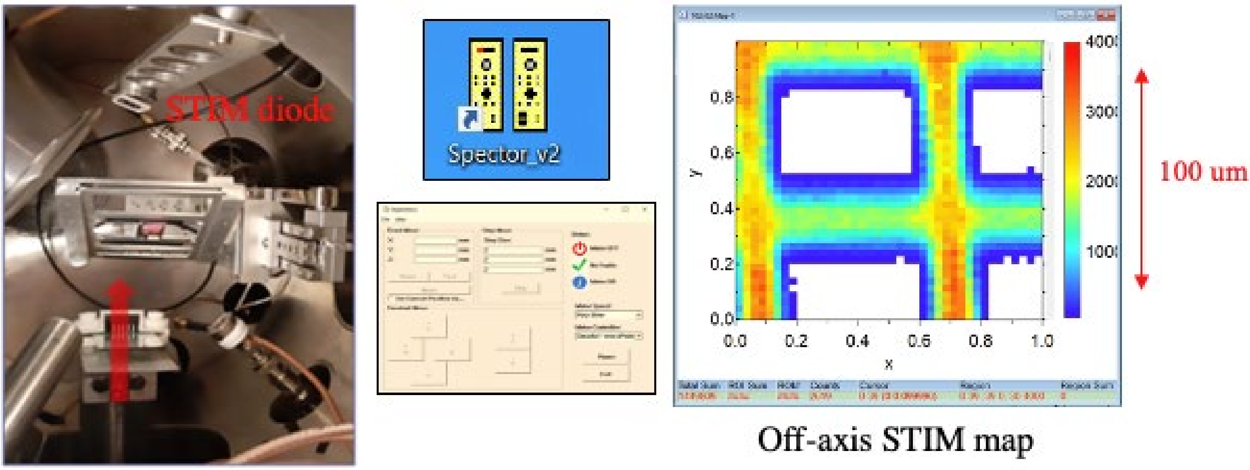

Fig. 4: First spatial resolution tests were performed by moving the sample mounted on the motorized piezo-stage.

As alternative to scanning the sample in front of the fixed ion beam, an electrostatic ion beam scanner was developed and installed at the 6 MV EN tandem short-focus position. During scanning the sample is held in a fixed position while the ion beam is scanned across the sample for two dimensional mapping of various sample characteristics (like local charge collection efficiency, radiation damage gradients, elemental and isotope concentrations, etc.) The electrostatic scanner consists of 4 parallel copper plates mounted on a cylinder positioned after the electrostatic focusing quadrupoles as shown in Figure 5. The left shows a schematic view of the setup while the left side shows the setup.

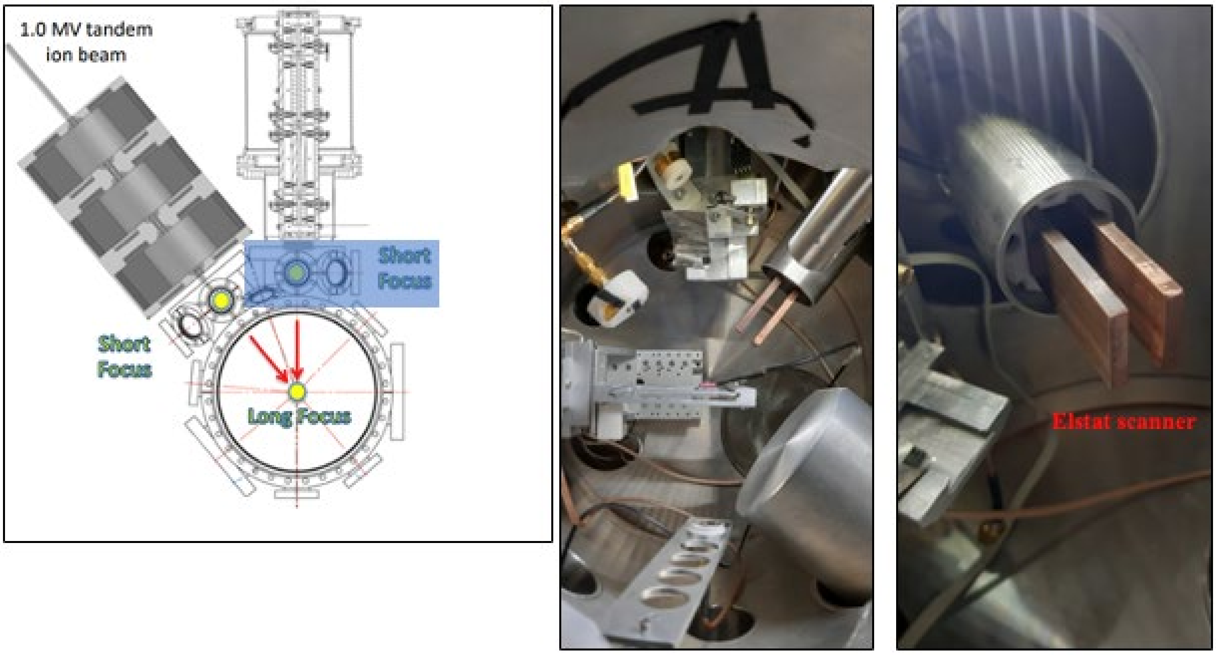

Fig. 5: An electrostatic scanner was made and installed at the 6 MV EN tandem short-focus position.

The scanner is connected to two KEPCO bipolar power supplies. Scanning is controlled by the local data acquisition software SPECTOR. A 400 Cu mesh was scanned on various scan sizes with a 2 MeV proton beam in order to confirm the proper scanning up to the maximum scan size, i.e. 900 µm (Figure 6).

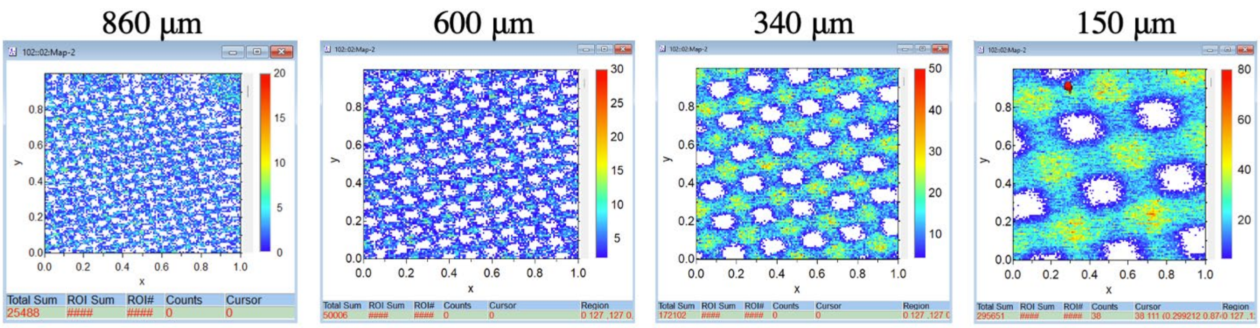

Fig. 6: On-axis 2MeV proton STIM maps of a 400 Cu mesh. The beam was rastered over the grid at four different scan sizes.

To estimate the beam spot resolution, a micro machined Ni grid equipped with fine structures with sharp edges is used. The corresponding low current (on-axis STIM) and high current (PIXE) maps are shown in Figure 7. From those maps, the beam spot was estimated as 7 µm for low current mode and 36 µm for high current mode accordingly.

Additional tests have been carried out in high-current mode with a 12.8 MeV C^{4+} as well as a 12 MeV Si^{4+} beam. From these tests the beam spot size was estimated to be ~22 µm along the vertical and 40 µm along the horizontal axis.

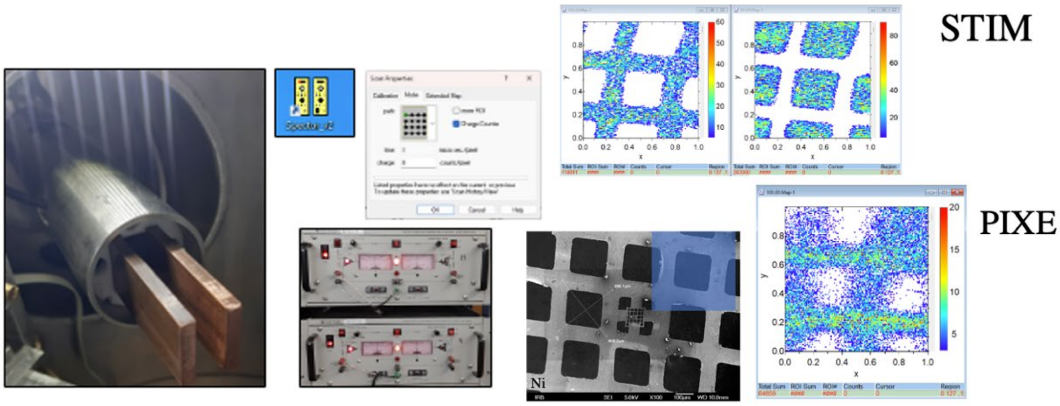

Fig. 7: The electrostatic scanner is controlled by SPECTOR. KEPCO bipolar power supplies are used. A micromachined Nickel grid was scanned. On-axis as well as PIXE intensity maps were obtained. In the former a beam spot of 7 μm was measured while in the latter the resulting resolution was 36 μm.

4. CONCLUSIONS

The beamline connecting the 'new' ion microprobe end-station E3 (DuMi) to the 6 MV EN tandem accelerator has been equipped with an electrostatic quadruplet lens, enabling the focusing of ion beams in the basis of *E/q* ratio (i.e. independent of the ion's mass). Microscopic ion beam analysis images can be obtained either by moving the target or by means of scanning the ion beam with the use of an electrostatic deflector. The tests performed on the newly developed electrostatic focusing and ion beam scanning setup showed beam spots of 7-30 μm in diameter. With the activities performed and reported herein, milestone M26 has been achieved. The electrostatic quadruplet performance in the focusing of even heavier ion beams, i.e. Cl, Au, I, will be further investigated in the near future.

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ANNEX: GLOSSARY

Acronym	Definition
DiFU	Dual-Beam Ion Irradiation Facility for Fusion Materials
EPICS	Experimental Physics and Industrial Control System
IBIC	Ion beam induced current
PIXE	Particle Induced X-ray Emission
RBI-AF	Ruđer Bošković Institute Accelerator Facility
STIM	Scanning Transmission Ion Microscopy
ToF ERDA	Time of flight elastic recoil detection analysis
TRIBIC	Time resolved ion beam induced current