A non-focussing retarding unit for Ar^+ ions

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During low-energy ion bombardment fascinating self-organized phenomena have been observed on surfaces of Ge, Si and other materials [1-3]. To enable the use of an existing 10 keV Ar^+ sputtering equipment for such low-energy experiments (500 eV – 1 keV) a retarding unit was calculated, designed and built. In the existing non-modified instrument a 1 mm diaphragm is arranged 12 mm in front of the substrate and a shadow projection of the diaphragm is accomplished. When retarding the ions by a high (positive) voltage at the target the grounded diaphragm and the irradiation mode should be maintained. Additionally, to have only a weak influence on the ion trajectories the retarding unit should be very short.

Retarding of ions or electrons without little overall effect on other beam parameters can be done with two or more electrostatic lenses [4], but there seems to be no design of a single immersion lens which fulfils the requirement $1/f_2 = 1/f_1\ (\Phi_1/\Phi_2)^{1/2} \approx 0$ with f = focal length, Φ = axial kinetic potential, index 1 = source side and index 2 = target side. For a short but not free-standing electrostatic lens (Φ'_1, $\Phi'_2 \neq 0$) O. Scherzer [5] gives the formula

$$\frac{1}{f_2} = \frac{1}{4}\left(\frac{\Phi_1}{\Phi_2}\right)^{1/4}\left(\frac{\Phi'_2}{\Phi_2} - \frac{\Phi'_1}{\Phi_1} + \frac{\Phi'_1\Phi'_2}{\Phi_1\Phi_2}L + \frac{3}{4}\int_{z_1}^{z_2}\frac{\Phi'^2}{\Phi^2}dz\right)$$

with $L = z_2 - z_1$ = length of the lens field and $\Phi' = d\Phi/dz$. In the case of a strong retarding field at the target, i.e. $\Phi'_2 < 0$, and $\Phi'_1 = 0$ Scherzer's formula has two contributions with different sign. This indicates that the realisation of a simple non-focussing retarding unit with $1/f_2 \approx 0$ should be possible. However, in the case of a free-standing immersion lens ($\Phi'_1 = \Phi'_2 = 0$) there is always a converging and a diverging contribution resulting in an overall converging behaviour.

Fig. 1 shows the final technical drawing of such a retarding unit, which is the result of some analytical considerations and numerical simulations using the Optics software [6]. The convex equipotentials in the left part of Fig. 2 result in a defocussing action, whereas the concave equipotentials at the right produce a focussing action. For Φ_1 = 10 kV and Φ_2 = 700 V this results in $f_2 \approx$ 330 mm although the effective length of the field is only 13 mm, see Fig. 2. For $\Phi_2 >$ 700 V the focal length f_2 increases strongly. Personal view and numerical simulation reveal that the inner and the outer diameter at the right side of electrode 1 together with the inner diameter of the right part (ring) of electrode 2 significantly influence the value of f_2. By means of changing this ring the focussing action of the retarding unit can be tuned. Also the excitation of the existing Einzel lens in front of the retarding unit may be used to generate the desired ion spot.

Special attention is paid to the insulator design, i.e. to creepage paths and triple points (electrode, insulator, vacuum). One critical distance between electrode 2 and a metal screw in electrode 1 is marked in Fig. 1. The distance between the two outer screws is larger because they have different azimuthal positions. The air escape channels of the outer drill holes are made in radial direction, see Fig. 3, to avoid a direct creepage path to the opposite electrode. In the case of the inner drill holes the air escape channels are in axial direction, see Fig. 4.

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The retarding unit was successfully tested (in vacuum) by applying 20 kV between the electrodes, which is a factor of 2 above the value necessary for the planned application. [7]

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6. Optics software by MEBS Ltd., London.
7. Fruitful discussions with Dr. V.S. Chernysh, manufacturing of the parts by H. Schühle and help with the high voltage test by C. Rochow are gratefully acknowledged.

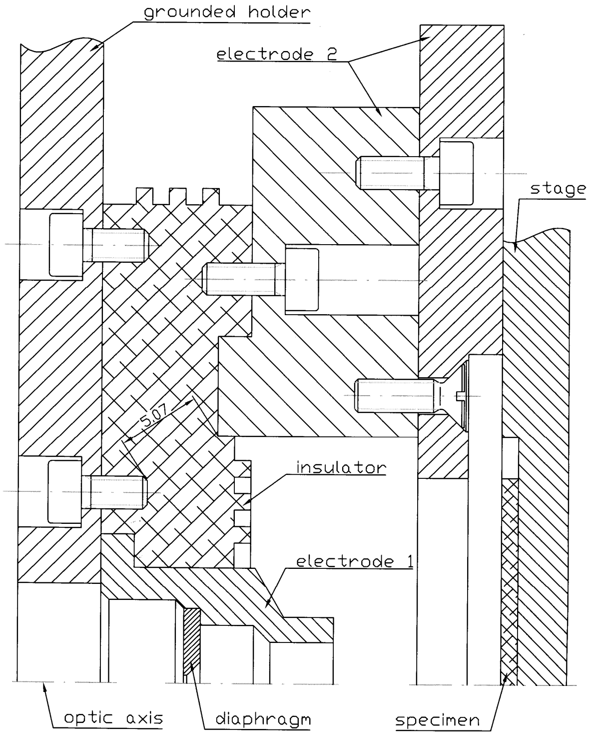

Figure 1. Technical drawing of the retarding unit. Electrode 2, the specimen and part of the stage are at a high positive potential.

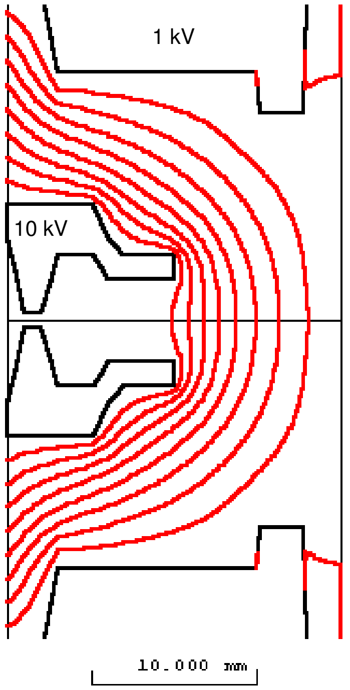

Figure 2. Equipotentials of a rough model of the retarding unit without the insulator. Increment = 100 V.

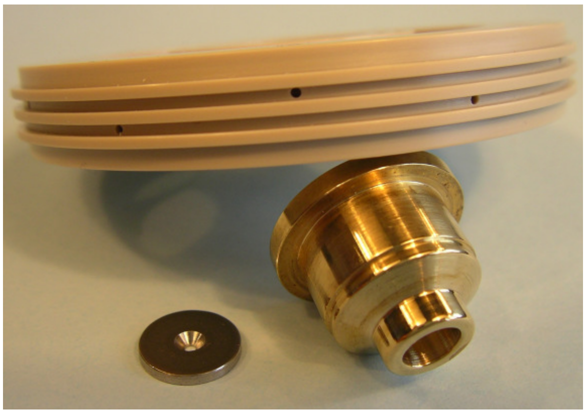

Figure 3. Insulator (PEEK), electrode 1 (CuAl8) and diaphragm (titanium, outer diameter = 9 mm) of the non-focussing retarding unit.

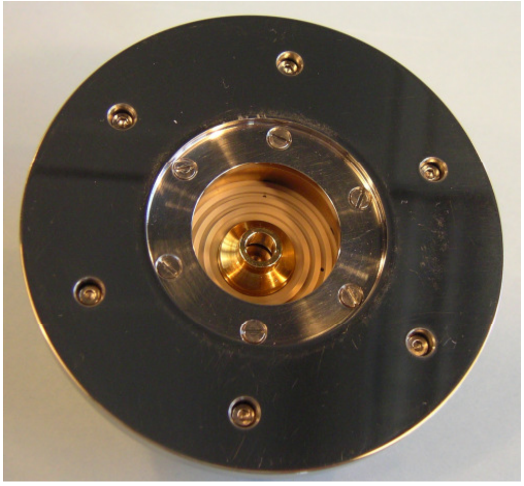

Figure 4. View onto the retarding unit from the target. Outer diameter = 80 mm.