The new ion beam extraction system for SMIS 37

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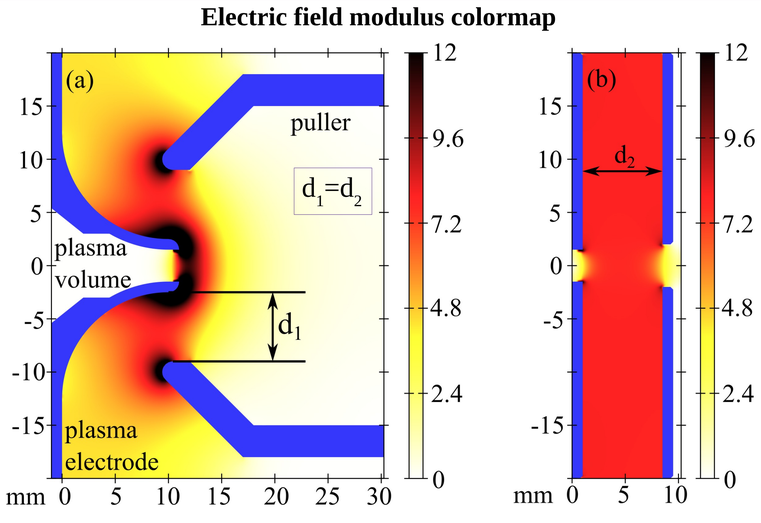
Abstract. The flat two-electrode extraction system was upgraded using a new approach to the extraction system design. It is based on the electrodes shape change which causes the redistribution of the electric field in the extraction region. The ion beam formation in the new geometry is more effective than in the flat one because of the more efficient accelerating field distribution. It broadens the available ion beam current density range.

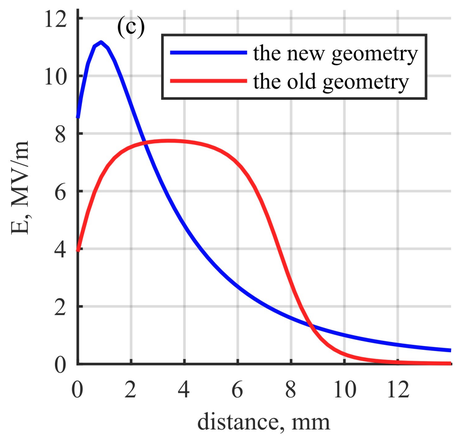
The experiment was carried out using a pulsed high-current electron-cyclotron resonance (ECR) ion source SMIS 37 with high power (100 kW) and high frequency (37.5 GHz) heating. The experiment was focused on confirming the advantages of the new approach, such as: a considerable decrease in the optimal accelerating voltage; a significant decrease in the ion flux to the puller; the effective formation of ion beams with higher current density. Formation of a proton beam with current density of up to 1.1 A cm^{-2} was demonstrated.

The new extraction system design

Electric field modulus colormap



Electric field profile on Z-axis

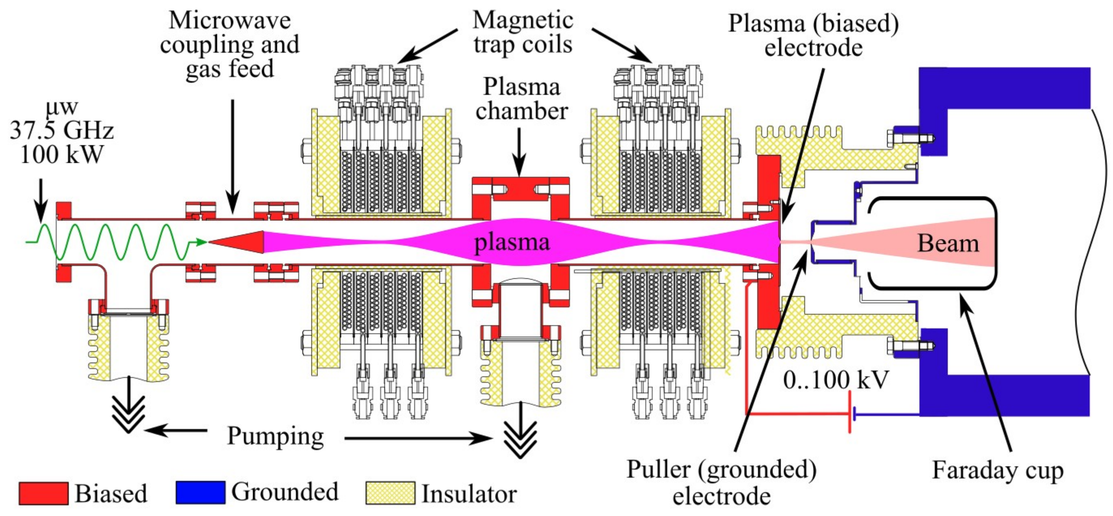


The key feature of the new approach is a shape of the electrodes. The new extractor forms an inhomogeneous electric field which is increased near the plasma electrode. It leads to decrease of the beam space charge. Thus, the perveance of the extractor increases.

The new geometry **features**

1. Ion beam formation with **higher** total current at the *same* extraction voltage
2. Ion beam formation with the *same* current but at **lower** extraction voltage
3. **Better** electrical breakdown resistance of the interelectrode gap
4. **Low** (even zero) ion current to the puller

The experimental facility: SMIS 37



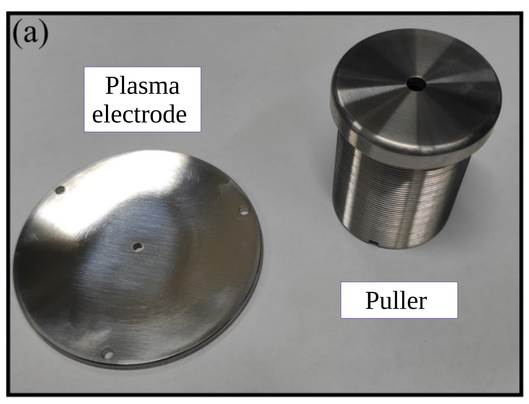
Facility **parameters**:

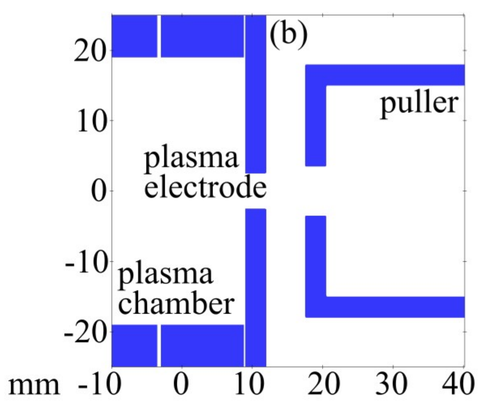
Microwave power – up to 100 kW
Microwave frequency – 37.5 GHz
Microwave pulse duration - 1ms
Extraction voltage – up to 100 kV

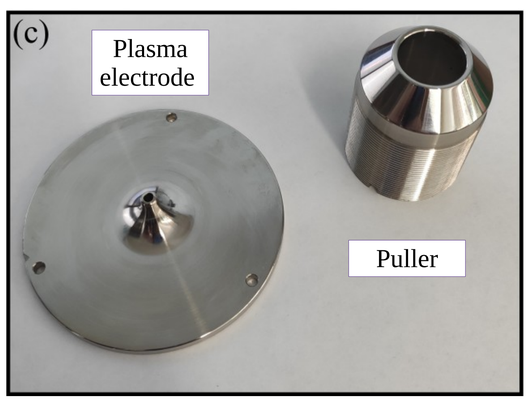
B_{max}/B_{min} = 5
Maximum B_{max} value = 4T
Distance between plugs – 250 mm
Inner chamber diameter – 38 mm

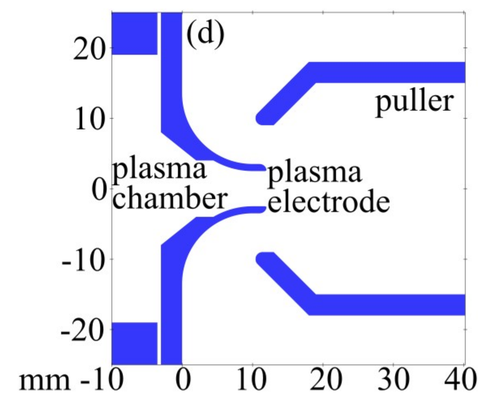
The working gas: H_2

The beam extraction system









The electrode photos and the extraction system cross sections for the flat geometry (a, b) and the system with inhomogeneity of the electric field (c, d). The puller aperture in the latter case is several times larger than in the flat one.

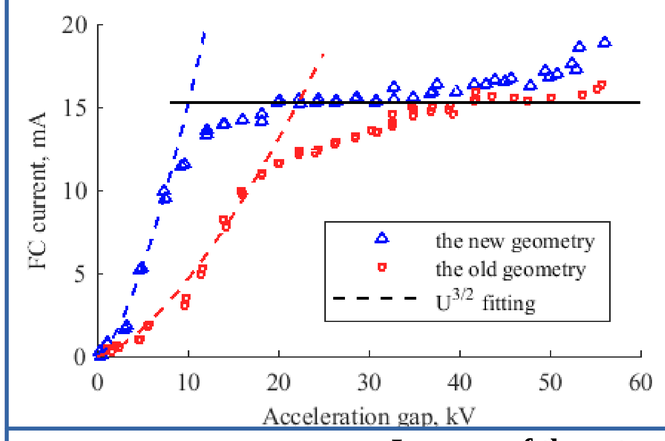
Extractor geometry cases:

1) plasma electrode aperture: D = 3 mm, interelectrode distance: L = 7.5 mm
2) plasma electrode aperture: D = 5 mm, interelectrode distance: L = 5.5 mm

Aspect ratio: a = L/D
determines the effectiveness of the new extractor.

The extractor with higher aspect ration creates more inhomogeneous field.

Decrease of the optimal extraction voltage

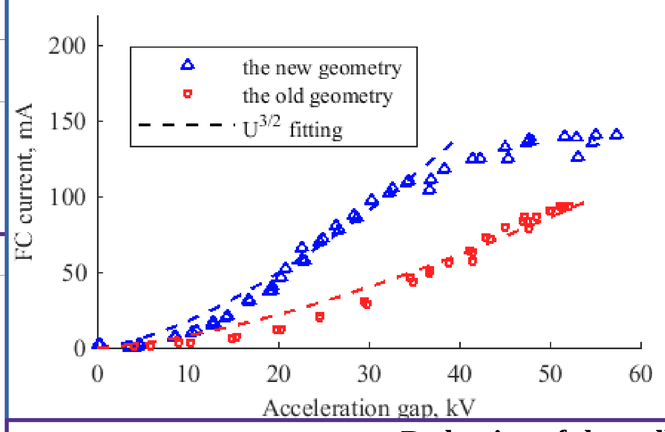


Case: D = 3 mm, L = 7.5 mm.
Aspect ratio: a = 2.5.

The optimal extraction voltage is decreased for the new geometry by a factor of 2.

Perveance ratio:
P_{new} / P_{old} = 3.3

Increase of the extracted current

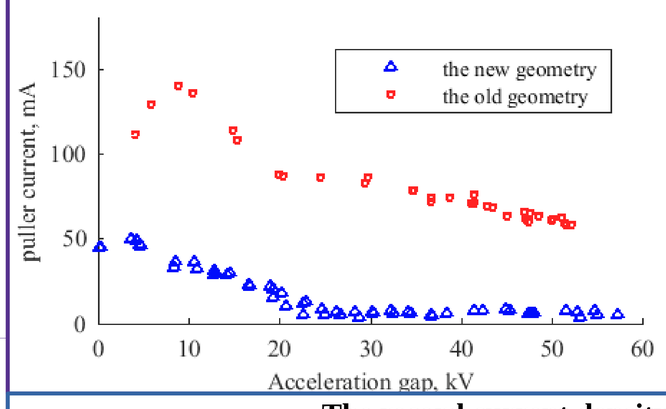


Case: D = 5 mm, L = 5.5 mm.
Aspect ratio: a = 1.1.

The increase of the total extracted current is observed for the new geometry.

Perveance ratio:
P_{new} / P_{old} = 2.3

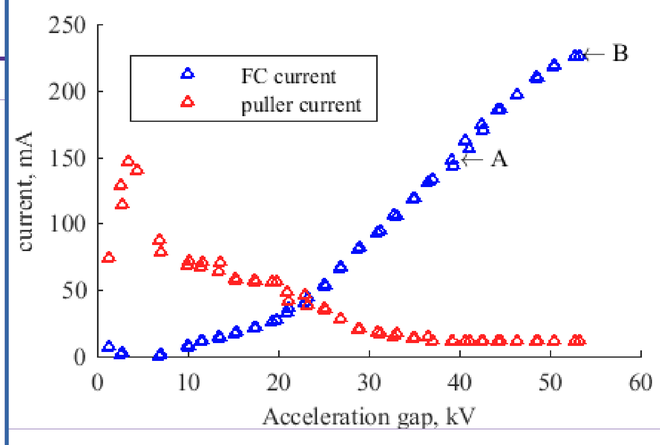
Reduction of the puller current



Case: D = 5 mm, L = 5.5 mm.
Aspect ratio: a = 1.1.

A significant decrease of the puller current is observed for the new geometry.

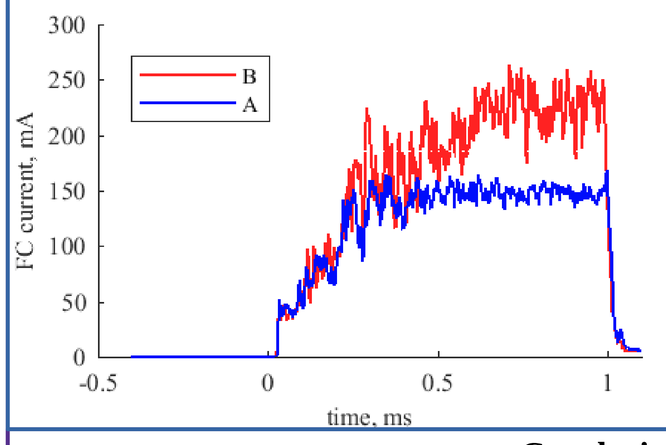
The record current density beam formation



Case: D = 5 mm, L = 5.5 mm.
Aspect ratio: a = 1.1.

The new extractor allows to form the beam with a record for ECR ion sources current density.

The beam with current density more than **1.1 A cm^{-2}** was obtained.



The extracted current oscillograms at points **A** (150mA at 40kV) and **B** (225mA at 53kV) are shown on the left.

Conclusion

The experiment proved the assumptions about the effectiveness of the new extraction system design:

1. The optimal extraction voltage **decrease** under the same conditions
2. The total extracted beam current **increase** at the same voltage
3. A significant puller current **reduction** was observed for the new geometry
4. The new extraction system is **more effective** for higher aspect ratio

The experimental demonstration of the new extractor effectiveness makes it possible to proceed the next steps of the implementation at various facilities.

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