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Smart solutions for vacuum and ion beam technologies

Two-rod-antenna microwave injection system for production of circularly polarized microwaves in cylindrical ECRIS cavities

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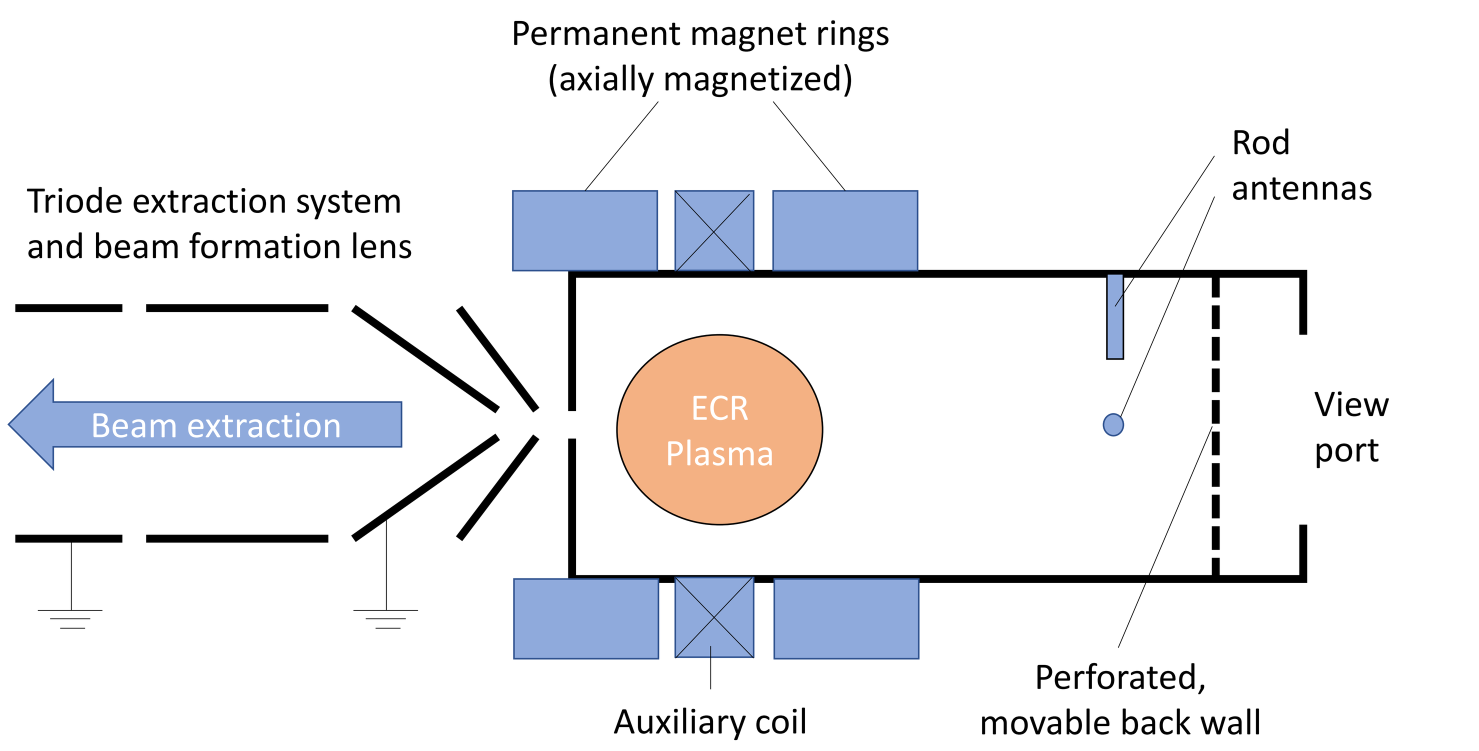
Motivation

- Electron Cyclotron Resonance Ion Sources (ECRIS) = state of the art sources of low, intermediately, and also highly charged ions e.g. for ion implantation and medical particle therapy
- In 2013, DREEBIT started with the design of a table-top sized ECRIS delivering light ions for nuclear physics experiments [1] and linear-accelerator-based proton therapy for cancer treatment [2]
- Requests for higher ion currents → search for ways of improving the energy transfer from microwave to electron heating
- Developments in the last few years in semiconductor-based microwave generator technology allow for a simple creation and transportation of phase shifted microwave signals to an experimental setup

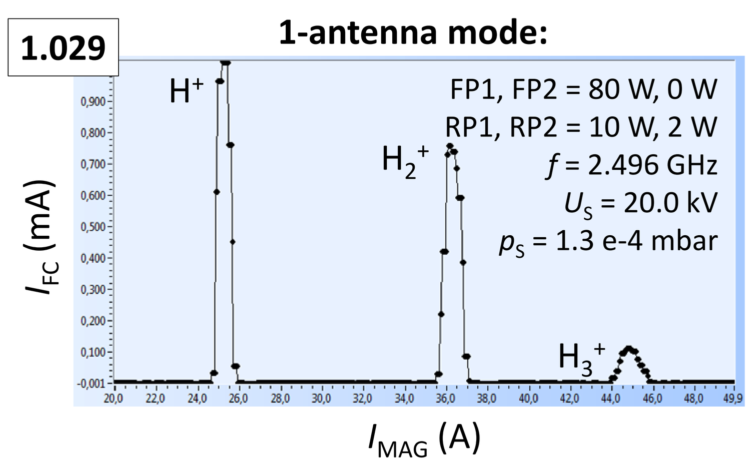
→ We present the advantages of using a two-rod-antenna microwave injection system for the production of circularly polarized waves directly inside a cylindrical ECRIS cavity

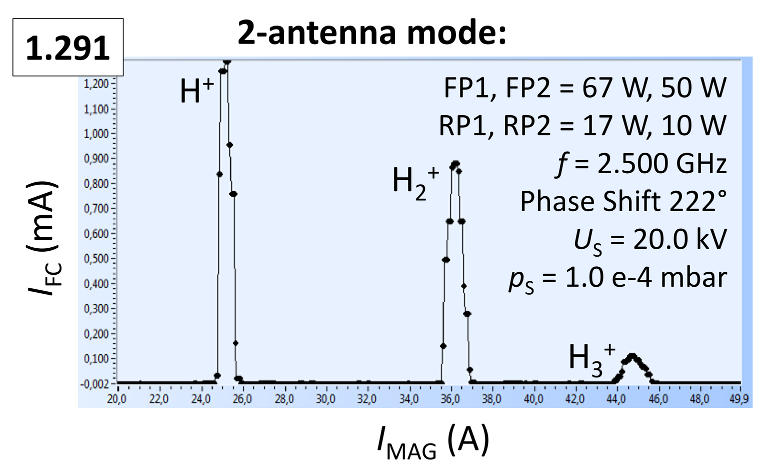
Experimental setup



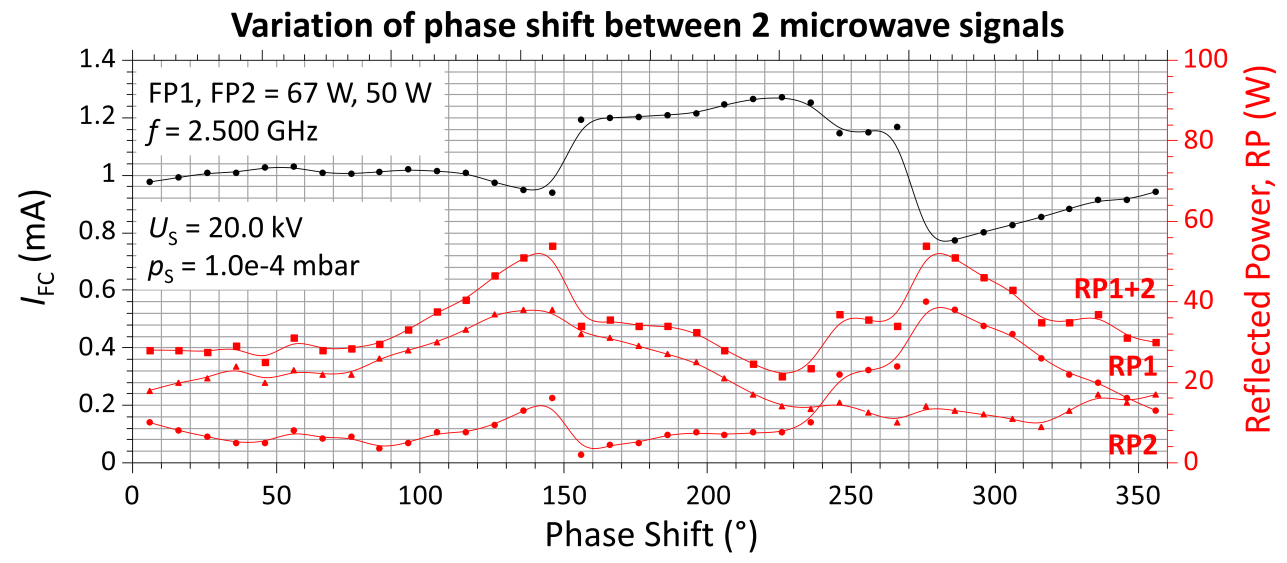
- Dresden ECRIS 2.45M-2A = a derivative of the Dresden ECRIS 2.45M [1]
- Antennas are connected to a solid state microwave generator developed by SAIREM SAS providing two signals with an adjustable phase shift from 0 to 360° via coaxial cables
- A beamline including a 90° bending magnet and Faraday cups are used to analyze the extracted ion beam
- An optical camera setup allows for observing of the radial plasma distribution through the perforated back wall of the ECRIS cavity and a view port window on the vacuum vessel

H^+ production using 1 and 2 antennas

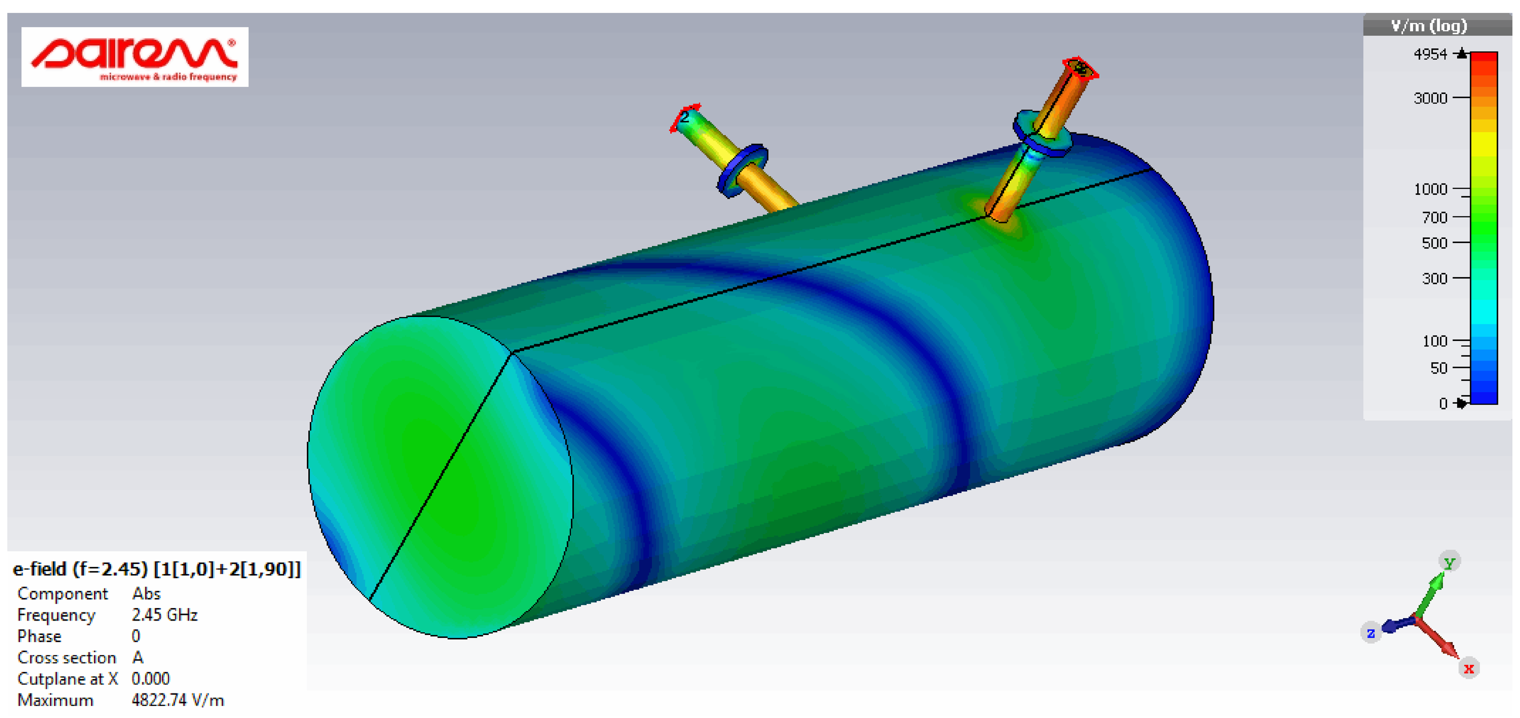




- The new ion source setup was commissioned in 1-antenna mode, i.e. only one antenna was fed with forward power (FP) of up to 100 W
- At 80 W, the increase of H^+ current stagnated at 1.06 mA, higher power did not lead to an increase in current anymore
- When the second antenna was switched on an equal power distribution of FP1, FP2 = 40 W and a microwave signal phase shift of ca. 200° instantly lead to a H^+ current of 1.13 mA
- After further tuning and increase in power, the H^+ current could be raised to 1.3 mA

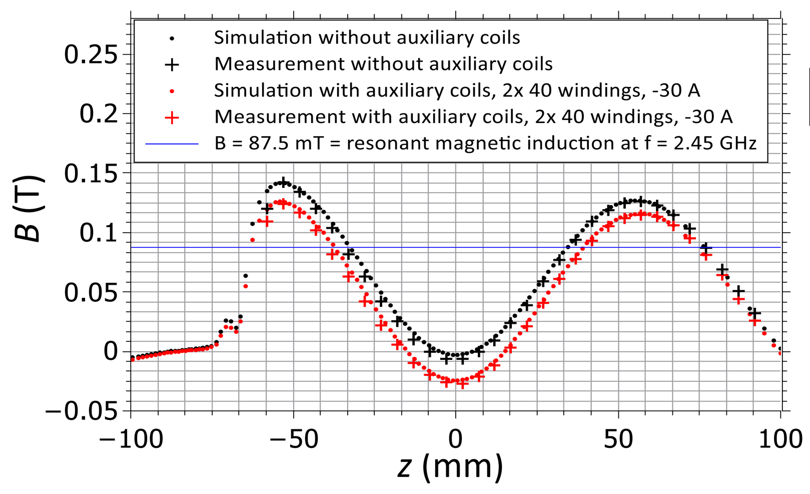


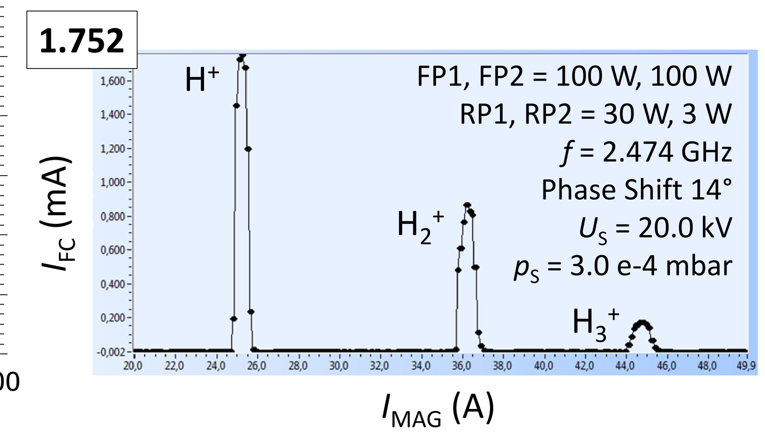
Microwave simulations



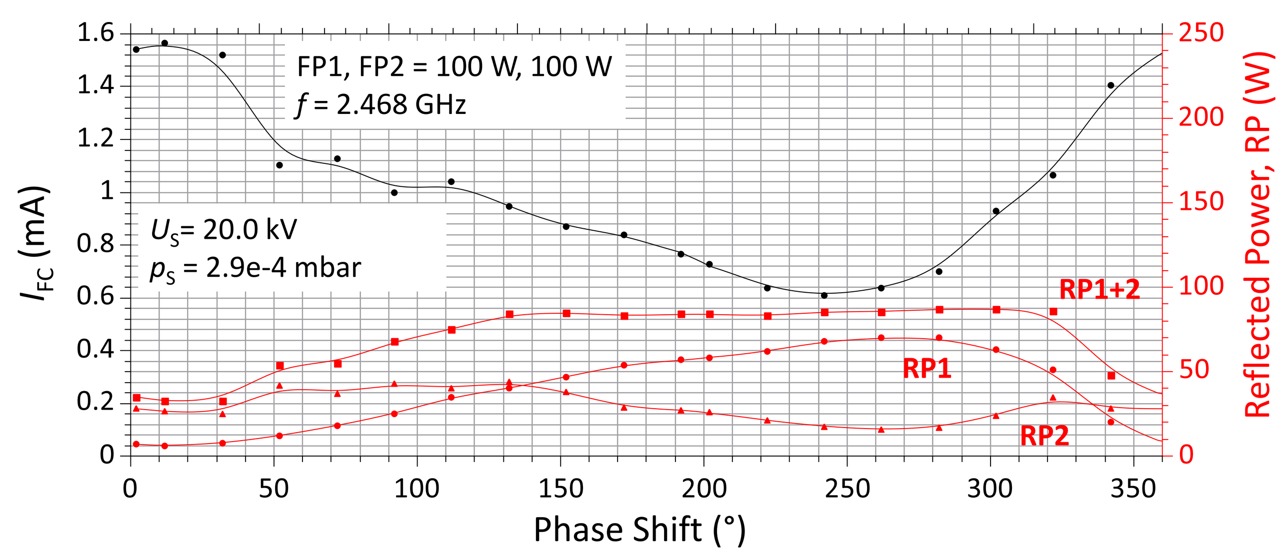
- Subsidiary studies performed by *L. Latrasse* of SAIREM SAS as well as *E. Zakutin* and *M. Laabs* at Technical University of Dresden helped finalizing the design of the two-antenna microwave feed
- The SAIREM simulations verified the working principle of two antennas under a geometrical angle of 90° and 90° phase shifted signals producing a circularly polarized wave, see picture above
- TU Dresden provided corrections of the exact antenna length and position for optimum power transfer towards the plasma

Optimization of magnetic field distribution in relation to circularly polarized microwave feed





- Auxiliary coils used to modify magnetic field for maximum H^+ current output
- Lowering minimum *B*-field leads to approx. 180° change in current vs. phase shift characteristics
- Possibility of adjusting phase shift allows for controlling where within the magnetic field power is absorbed → extracted current increased by 70 % compared to one-antenna ion source version



Literature and Patents

[1] M. Kreller et al.: "An ECRIS Facility for Investigating Nuclear Reactions in Astrophysical Plasmas", *Proceedings, 22nd International Workshop on ECR Ion Sources*, Busan, Korea (2016) pp. 59-63

[2] A. Degiovanni et al.: "Status of the commissioning of the LIGHT prototype", *Proceedings, IPAC'18*, Vancouver, BC, Canada (2018) pp. 425-428

[3] A. Philipp: „ECR-Ionenquelle und Verfahren zum Betreiben einer ECR-Ionenquelle" Patents No. DE 102019111908 (09/05/2019), US 11094510, EP and CN patents pending

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