Abstract:
The department of extraterrestrial physics of the University of Kiel is establishing a solar wind laboratory which will be used mainly for three purposes: calibration of space instruments interacting with the solar wind, research on space weathering of dust particles, and for fundamental plasma physics. The laboratory will be able to generate a well defined highly-charged ion flux, similar to the solar wind, at energies from 1- 450keV/q. To generate this flux, ions of different charge states are produced in a 10-14GHz Electron-Cyclotron-Resonance Ion Source (ECRIS).
Both, calibration and dust particle bombardment, need accurate values for the main beam parameters such as current, position and profile. While the current can be measured by a single Faraday Cup (FC), position and profile of the ion beam can be acquired with a Faraday Cup Array (FCA) moving through the beam. This array allows high resolution, accuracy and durability even for the expected current range (pA to mA) and a beam power up to 40W.

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Development of a position-sensitive Faraday-Cup-Array beam diagnostic for the solar wind laboratory at the University of Kiel

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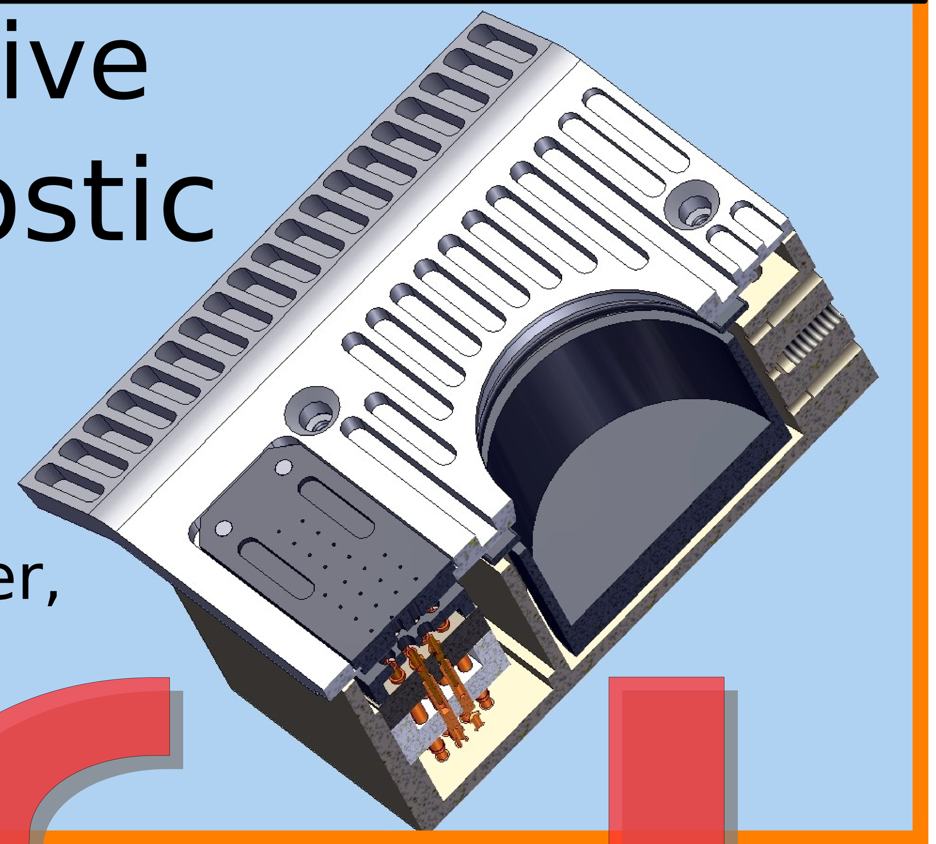
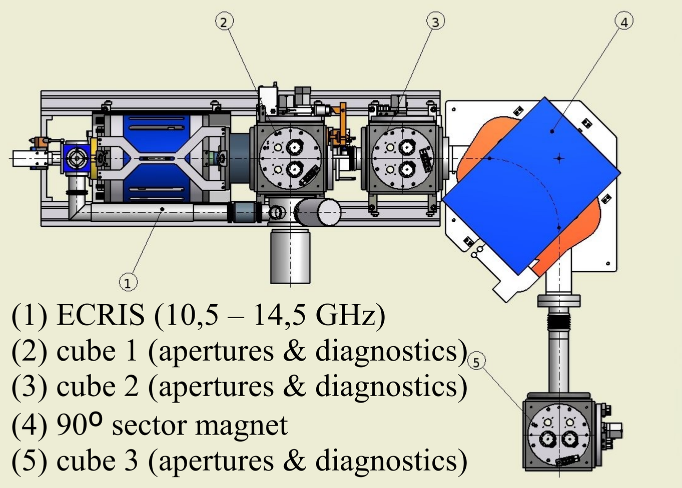


Overview & demands

Schematic of the ion source:



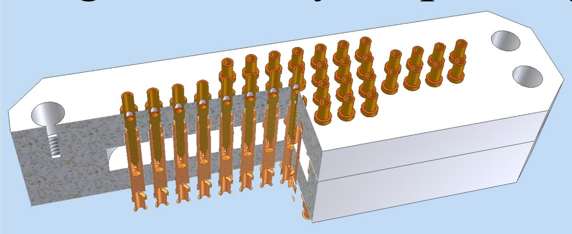
(1) ECRIS (10,5 – 14,5 GHz)
(2) cube 1 (apertures & diagnostics)
(3) cube 2 (apertures & diagnostics)
(4) 90° sector magnet
(5) cube 3 (apertures & diagnostics)

characteristics:
- beam power ≤ 40W
- beam current ≤ 2mA

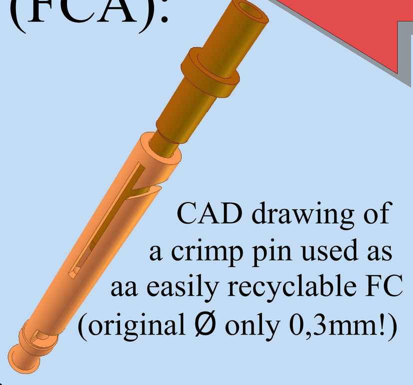
demands:
- position-sensitive measurements
- current resolution ≤ 100pA
- measurable range: 100pA to 2mA
- heat resistance

Faraday Cup Array

High resolution profile measurements using a Faraday Cup Array (FCA):



CAD drawing of the FCA



CAD drawing of a crimp pin used as aa easily recyclable FC (original Ø only 0,3mm!)

Resolution: 2500 dpi in position
50 pA in beam current

Faraday Cup

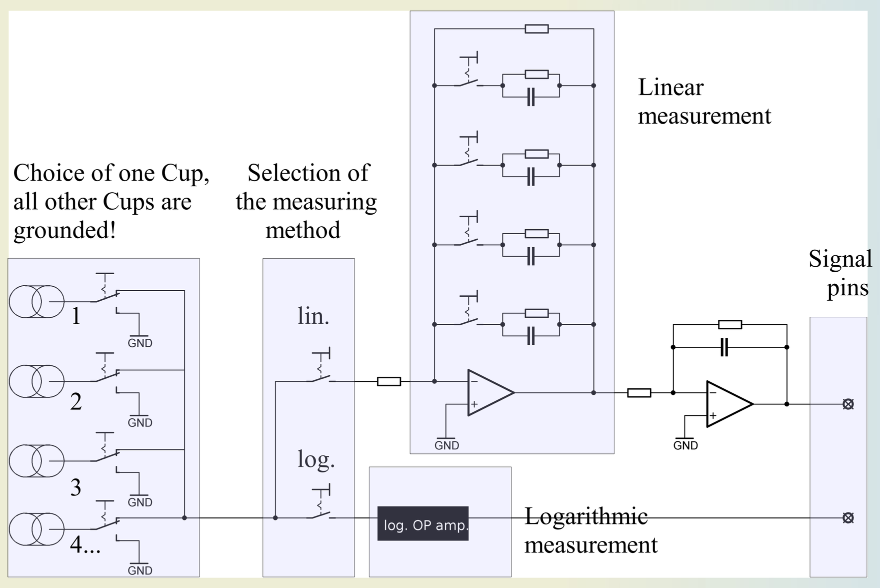
Spectra measurements using a single Faraday Cup (FC):

CAD drawing of the FC

Resolution: 50 pA in beam current

Electronics & measurements

Schematic of the measuring electronics:



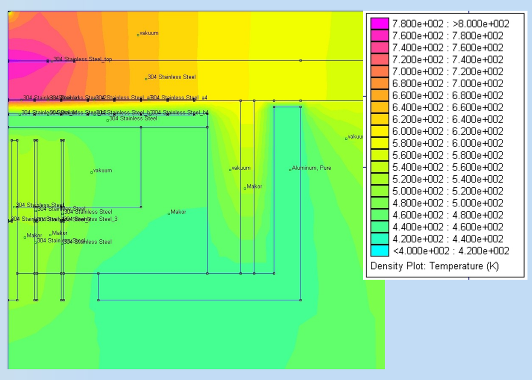
Depending on the operation (FC or FCA measurement), the current ranges from pA to mA. As a profile scan needs about 4000 single measurements with currents varying in a wide range (up to 8 decades), a minimum measuring frequency of about 200Hz and high resolution in this wide range are essential. For fine peak detection during a spectrum scan, here also a high measuring frequency and resolution are needed. To achieve adequate resolution and speed, for both operations two different measuring methods are used (as seen above):

operation:	range:	method:	resolution:
profile	pA – µA	linear	5pA – 5nA (depending on range)
spectrum	µA – mA	logarithmic	≈100nA (not certified yet!)

The measuring procedure is controlled by a microcontroller. This means in case of the linear method (more complicated method):

- choosing the measuring method (linear) and then a routine:
- moving the detector one step forward towards the beam
- connecting one cup to the chosen measuring electronics
- changing dynamically the measurable range
- measuring the current (as voltage with a 10bit Analog-Digital-Converter)
- saving the measured current as a function of the position
- moving out and transmitting the data to the PC

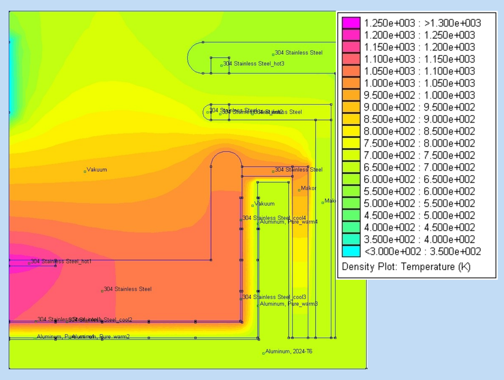
Heat simulation for the FCA:



P_{beam} ≈ 40 W
$Ø_{beam}$ ≈ 10 mm

The simulation¹ shows a resulting temperature of about 780 K for the frontplate and 550 K for the inside during a profile measurement with the FCA.

Heat simulation for the FC:

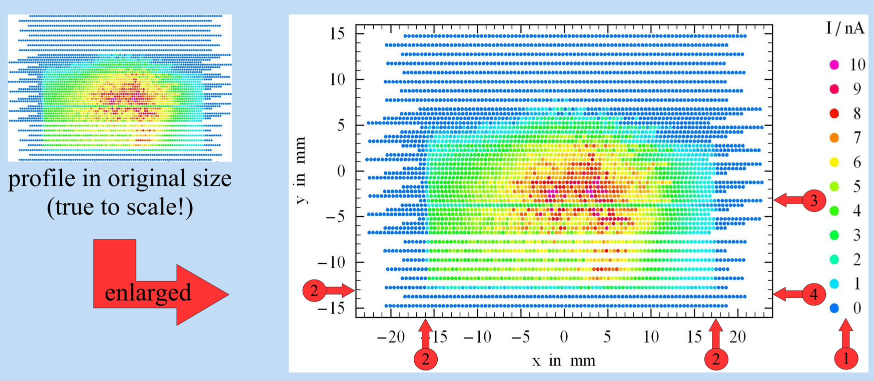


P_{beam} ≈ 40 W
$Ø_{beam}$ ≈ 10 mm

The simulation¹ shows a resulting temperature of about 1250 K for the FC and 650 K for the inside during a spectrum measurement with the FC.

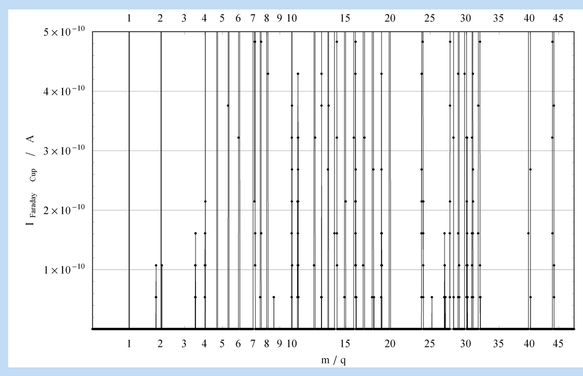
¹The simulations were made using the program MIRAGE 1.0 by David Meeker (http://femm.foster-miller.net/wiki/Download). Special care was taken to convert the symmetry of the FCA into a cylindric symmetry as it is necessary for the program. The main parameters for heat flux and radiation (cross-section and surface) in vacuum should have the same values in both symmetries. Other important parameters (coefficients for absorbtion and emission and heat conductivities) were defined as realistically as possible. The design of the detector aims to emit as much energy as possible mainly from the corrugated frontplate or directly from the FC into the vacuum to keep the inside cool. For good thermal insulation between frontplate, FC, and housing, Macor® is used. Due to the heat radiation to the inside of the housing, the outside of the detector is anodised black to optimize energy emission.

Analysis of the first measured profile:



This measured profile from cube 2 gives interesting information:
(1) high resolution in current measurement (data shows resolution of ≈50pA)
(2) high resolution in position measurement: profile shows images of the apertures of cube 2 (intensity decreases abruptly to 0)!
(3) apertures of the detector have to be well cleaned! Smaller apertures measure constantly a smaller intensity.
(4) no crosstalk can be detected (neither from proximate cups nor wires)

Analysis of the first measured spectrum:

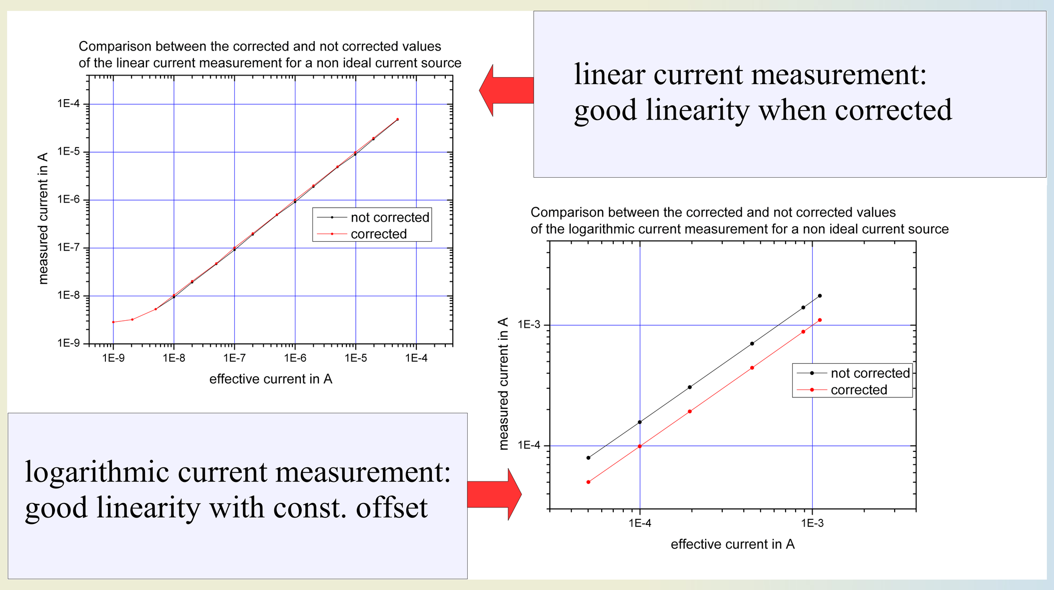


This measured spectrum in linear presentation confirms:
- the resolution for current measurements is ≈ 50pA!
- the noise from the electronics is well below 50pA!

→ the resolution of the electronics acts as a discriminator!

External measurements show that the noise of the electronics is about 1,5pA only! → higher resolution possible: 3pA with a 14bit ADC!!

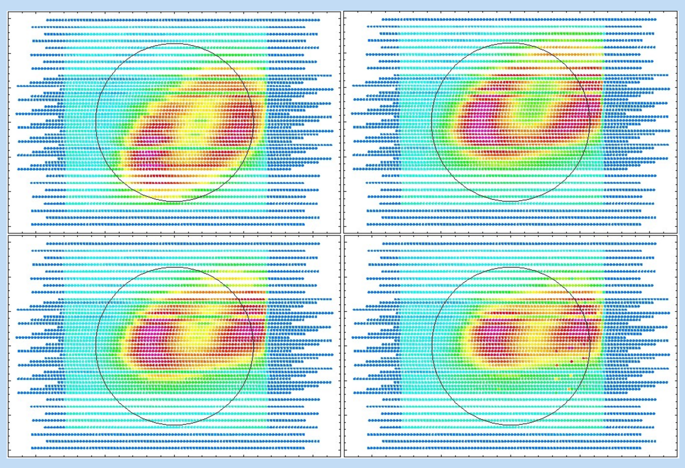
Conclusions for the current measurements:



linear current measurement: good linearity when corrected

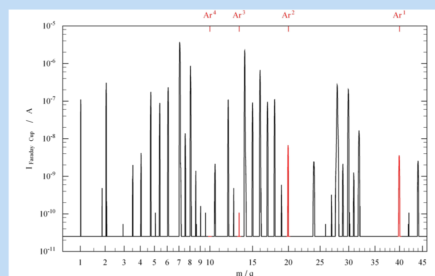
logarithmic current measurement: good linearity with const. offset

Further examples of profile measurements:



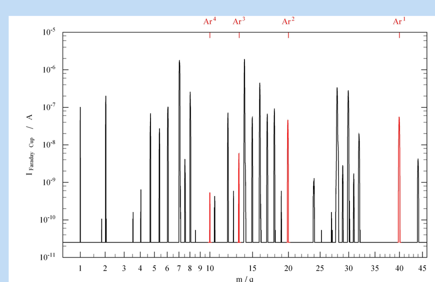
These profiles were measured by varying the distance between the extraction and the plasma-electrode from 13 to 16mm in 1mm steps.

Further examples of spectra measurements:



1st m/q spectrum measured in cube 3, the rates of Ar in different ionisation states are highlighted (red).

[the offset is added manually for logarithmic presentation purposes]



2nd m/q spectrum measured in cube 3 after addition of Ar to the plasma-chamber. All rates have decreased except the Ar rates at different ionisation states (again highlighted red).

contact:
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Conclusion and perspective:
This developed detector system represents a new way to measure the main beam parameters with high resolution in position and current withstanding a beam power up to 40W. The specific feature of this detector is that it can measure position and profile directly and gives absolute values for the beam current.

The resolution of the current measurement can be improved by using an ADC with a higher resolution. Even with 14bit (equals 3pA) resolution no noise should be seen. Instead of the logarithmic method, the measurements of the spectra could also be done with a second, adapted linear method increasing the measurable range.