Faraday’s Cup design

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Introduction

A Faraday’s Cup is a detector that detects the presence of charged particles, by accumulating on the surface of the detector.

Statement

The Faraday’s cup works based on the principles of electrochemistry and the conservation of electric charge.

Electrochemical process is the core principle behind Faraday's cup. When charged particles, such as ions or electrons, encounter a conductive surface (the collection surface of the cup), they can transfer their charge to that surface. This transfer of charge is facilitated by an electrochemical reaction between the charged particles and the conductive material of the cup's electrode.

This reaction creates a potential difference between the electrodes and the current integrator circuit which induce electric current that flows through an external circuit connected to the cup. This current is proportional to the number of charged particles that have been collected by the cup. By measuring this electric current, the number of charged particles that have impacted the cup's surface.

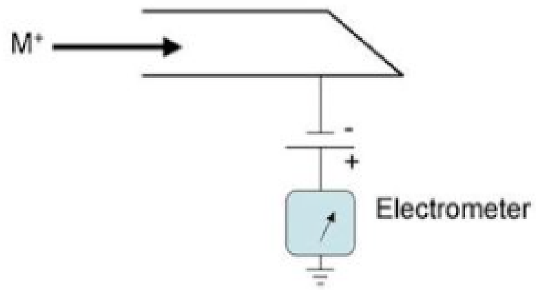


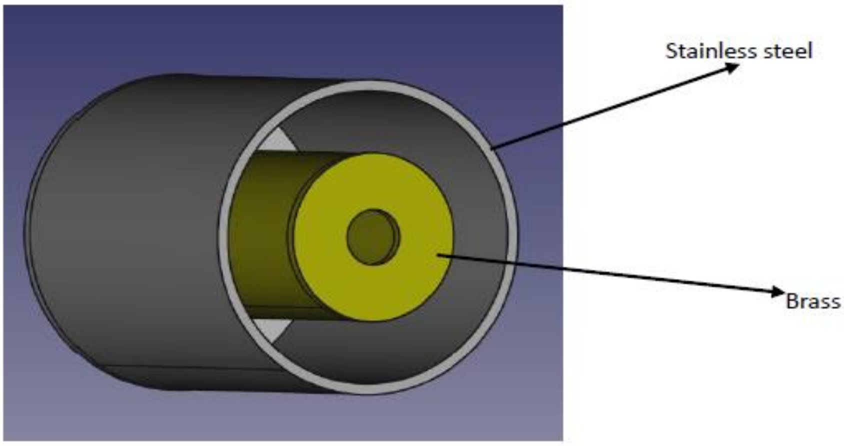
Fig. 1: Faraday’s cup in principle

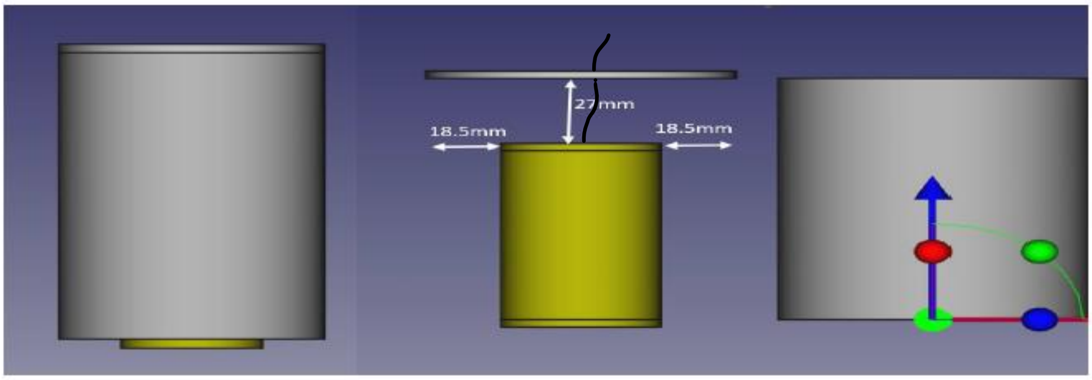
The design of the faraday’s cup is one of the factors that will decide whether it will work as wanted. This report will discuss the modules that have been studied so far.

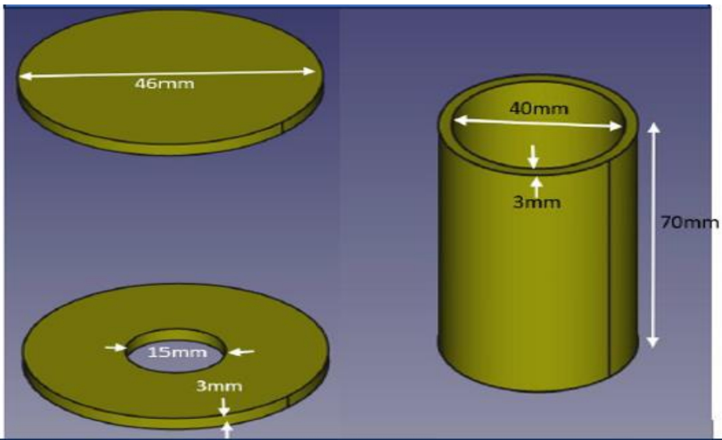
Module #1

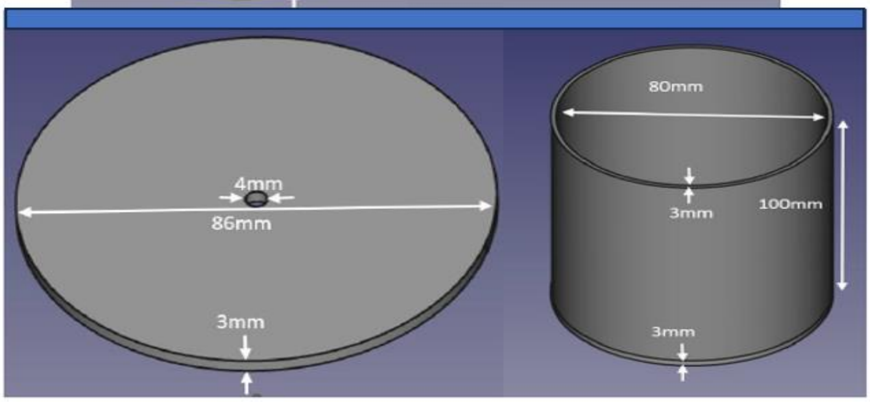
- The ions will enter through the hole into the brass cup generating current.

-The empty volume between the stainless steel and the brass will be filled with polystyrene.









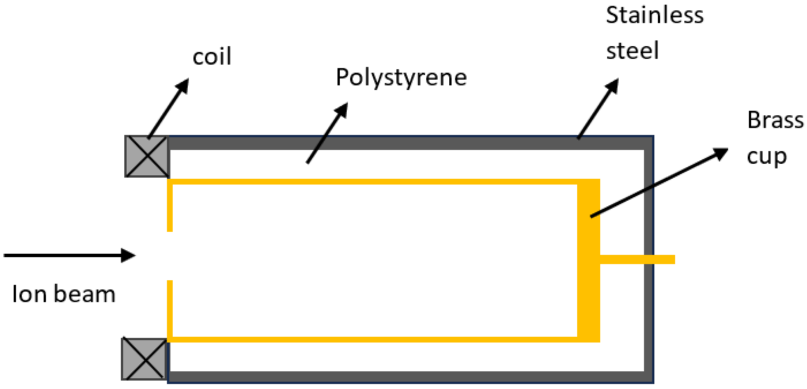
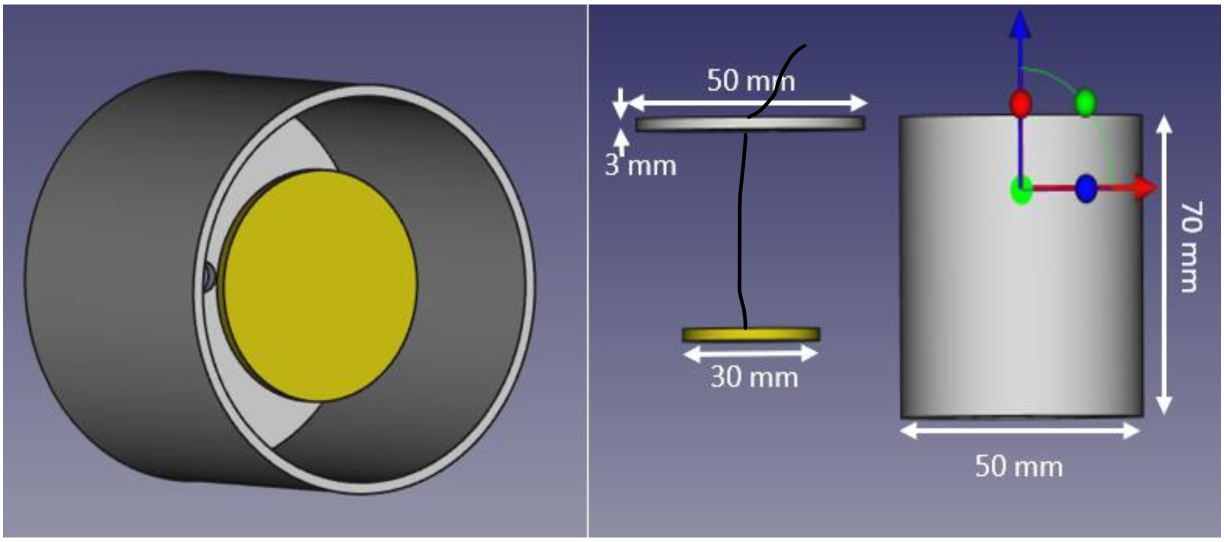


Fig.2: cross sectional area of module 1.

Module #2



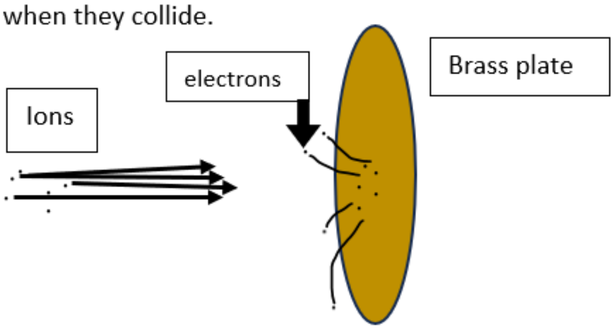
Yellow is brass, gray is stainless.

When the ion beam collide with the plate electrochemical reaction between them will transfer the charge to the plate that will generate current through the wire into the electrometer.

It is important to note that this design is not efficient as module 1 due to the possibility of the ion to bounce off electrons off the surface is a process called "electron scattering" which involves the interaction of atoms or particles with the electrons in the material of the conductive plate. This interaction can lead to changes in the direction and energy of the electrons as they bounce other charged particle off the plate's surface when they collide.

This will prevent an accurate measurement as these electrons carry charge that will be lost and thus current change.

However, this problem can be solved by implementing a tiny change that will be mentioned later.



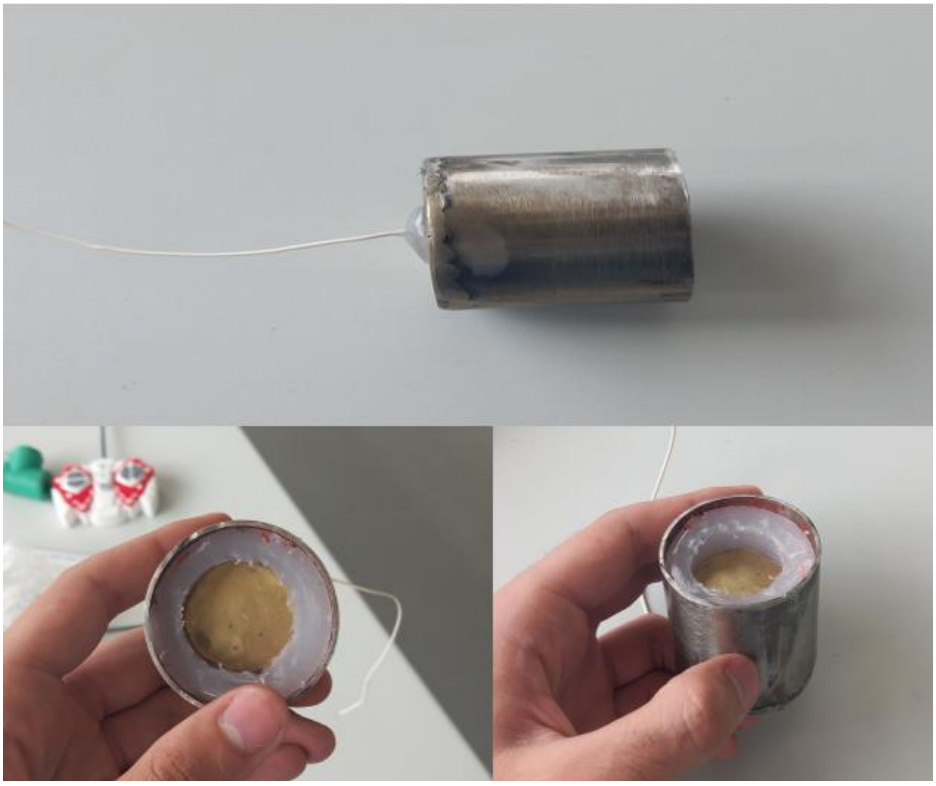
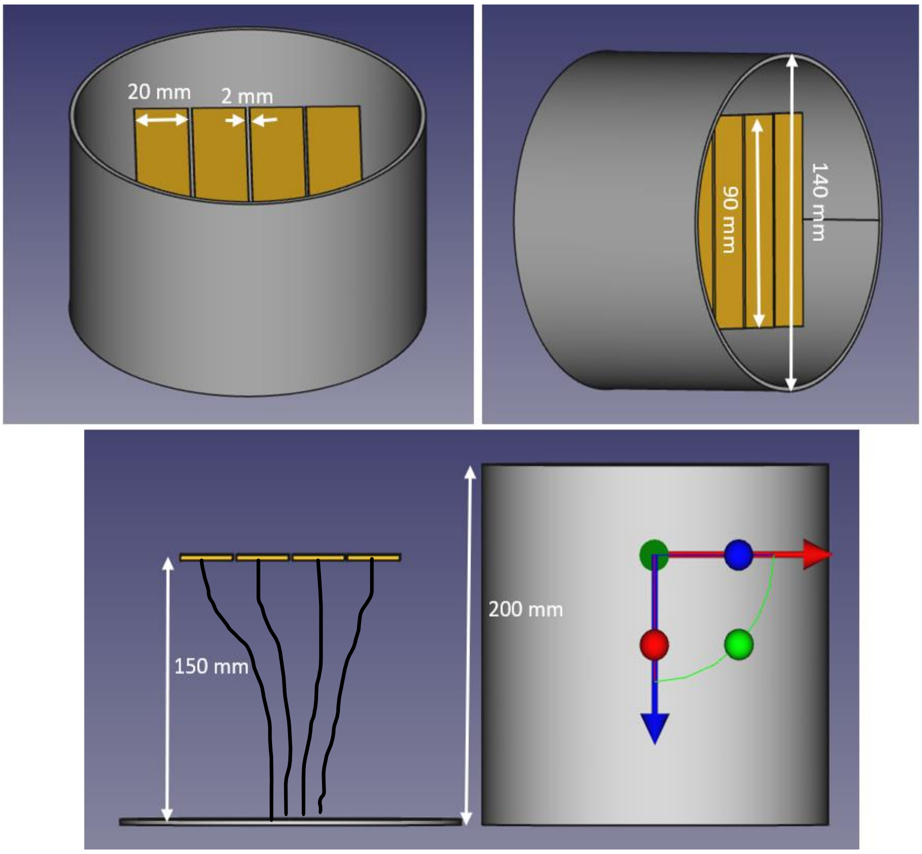


Fig.3: Module 2 made and ready to test.

Module #3



In this module the "electron scattering is not yet solved; however, the introduction of rectangular brass plates is to make this detector an array one.

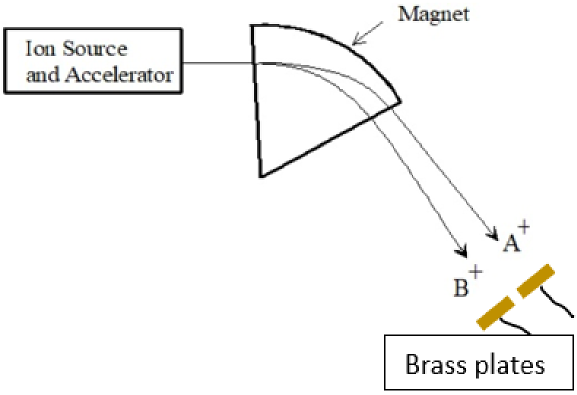
The problem with faraday's cup is that it can only be used detect only one type of ions in the mass spectrometer unless a flight time analysis was implemented which is not.

An array of faraday's cup can solve the problem as each plate can detect one type of ions according to their position (masses).

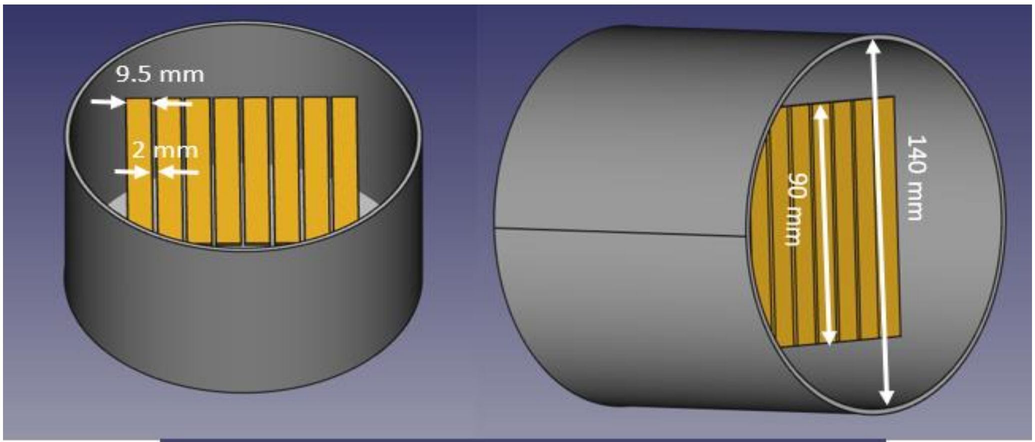
The accelerated ions go through a magnetic field which change their direction, since all ions in the experiment have the same charge, they will experience the same moving force. However, due to the different masses of each ion, they will move in a different directory i.e., the heavier the ion the longer the arc will take.

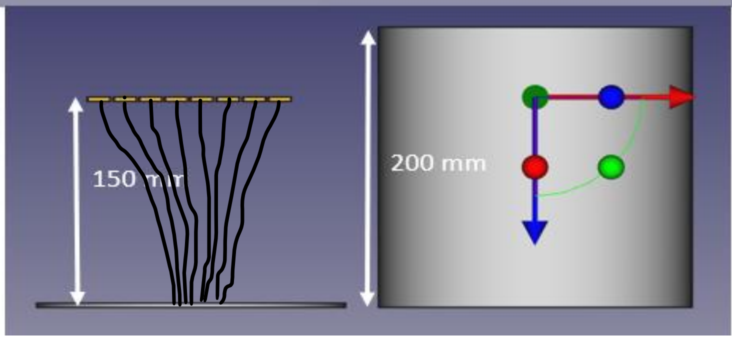
Looking at the diagram, it can be concluded that the more plates implemented the larger the ion type range that can be detected.

Which will directly affect module 4 the detector.



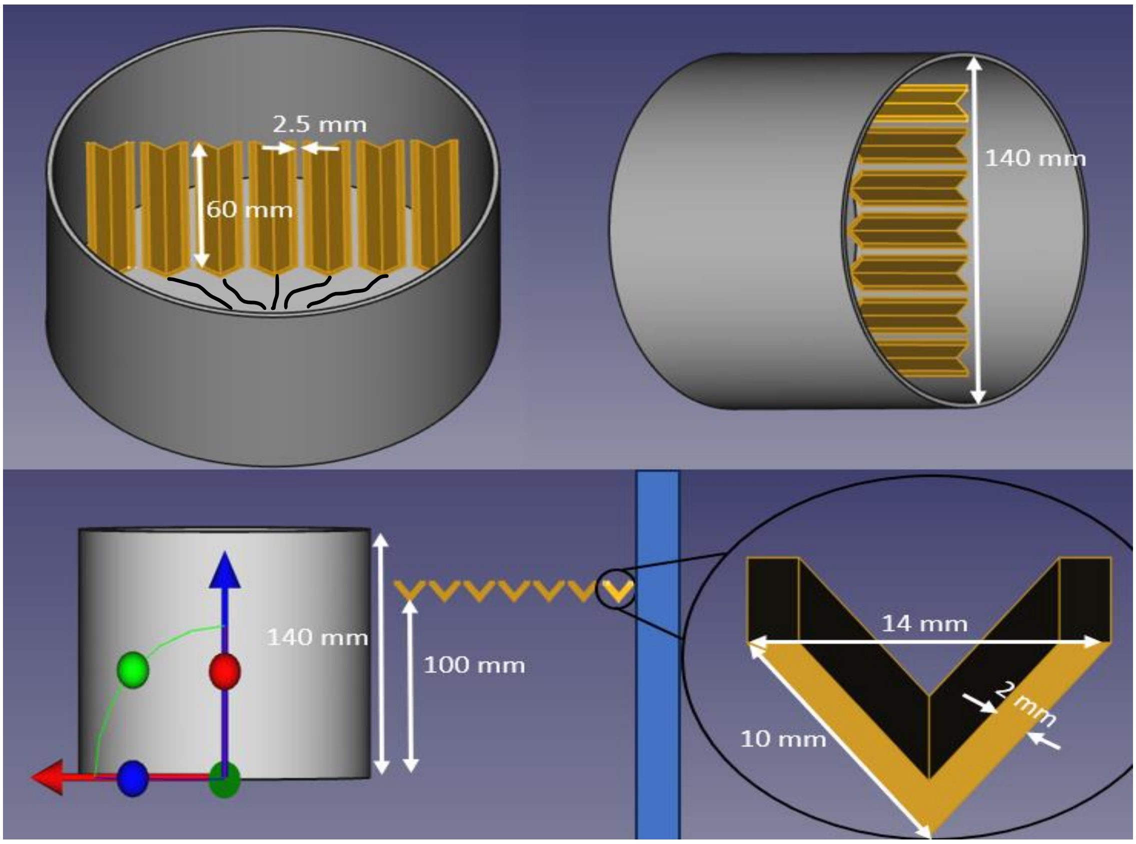
Module #4



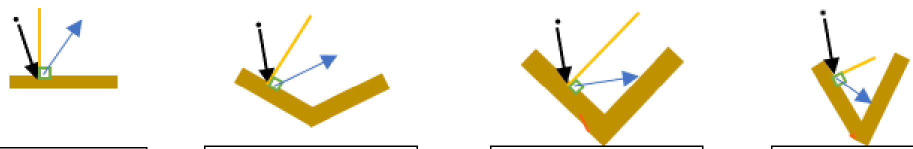


Same as module 3, but with more plates.

Module #5



The final module reflects modules 5, but with replacing the plate-like brass into V-like shape. This will reduce the effect of "electron scattering'' since when it happens the shot electrons will go in the direction of ion trajectory. This will leave the following cases:



Brass plate	Brass V-shape Obtuse angle	Brass V-shape 90^0 angle	Brass V-shape Acute angle

: normal to surface ; : ion direction ; : electron direction

What this shows is that the electrode shape actually matters because as the angle of the V-shaped is 180° (plate) or is obtuse the scattered electrons will leave; however, when it is 90° the electrons are more likely to hit the plate, but when it is acute angle the electrons are guaranteed to hit more than once which will drop the loss to minimum.

In summary

Faraday's cup operations are based on the principles of electrochemical deposition and charge conservation. It provides a way to measure the intensity of charged particle beams by collecting the particles on a conductive surface and quantifying the resulting electric current. And the design of the Faraday cup has an effective factor on the performance of the detector.