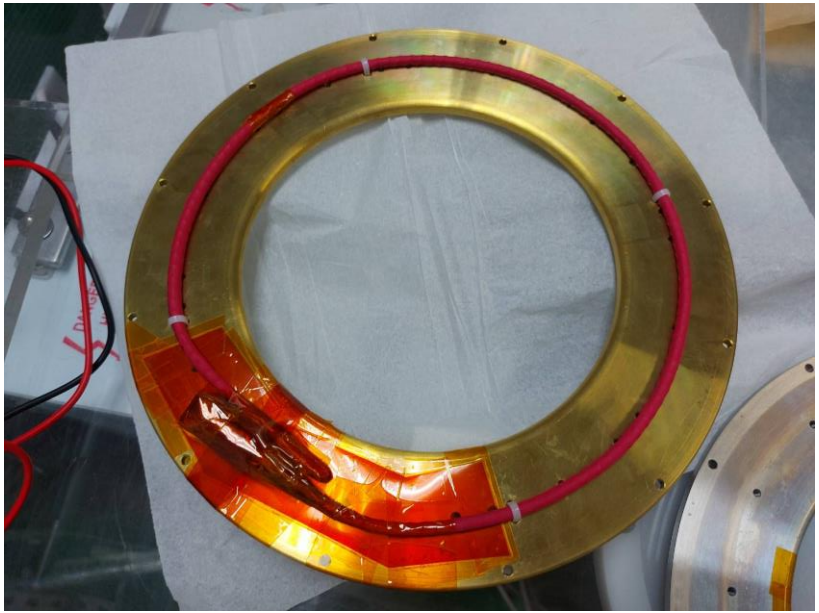
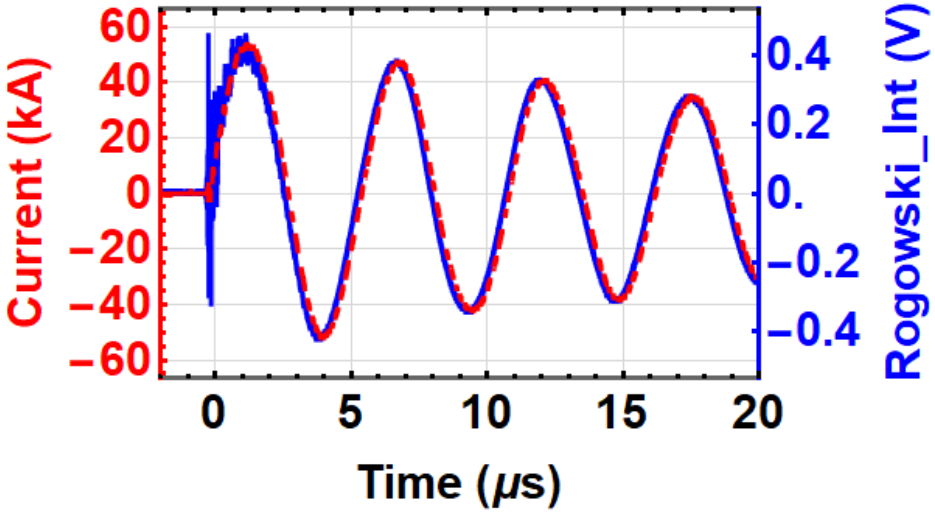
The procedure of the third version of the Rogowski coil





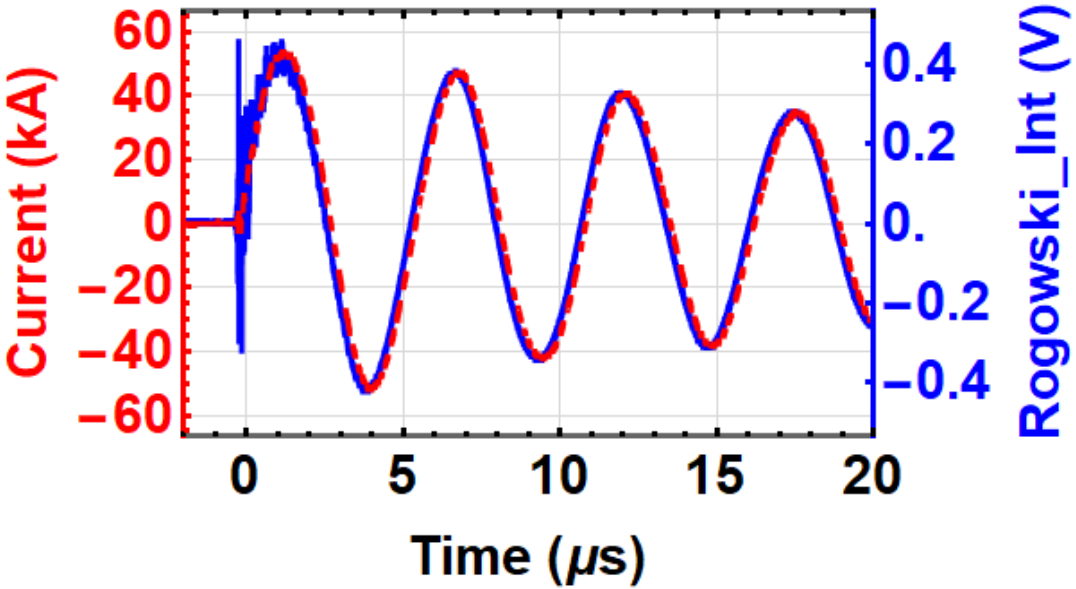
Yi-Zuo Pan King
Institute of Space and Plasma Sciences
National Cheng Kung University

Group meeting
Institute of Space and Plasma Sciences
National Cheng Kung University
2023.2.23

Summary

The third version of the Rogowski coil is finally completed

- I(kA) = (123.5 ± 0.8)*V_Rog_Int(V)
- The calibration is done, time delay = -138 ± 2 ns.



Outline

- Concept and structure of the Rogowski coil
  - Helical coils must be closed curve
- Placement of the Rogowski coil
- Prevention of arcing
- The design of the previous two versions
  - Updating to a thinner Rogowski coil
  - Production flowcharts of the previous two versions
- Required tools for making Rogowski coil

Outline

- Component of BNC connector
  - Cross-sectional diagram of a coaxial cable
- Assembly process of BNC connector and the RG-58 coaxial cable
  - Disassembling the coaxial cable
  - Insertion probe and soldering
- Process of the Rogowski coil
  - Disassemble the coaxial cable
  - Soldering of the wire and coaxial cable
  - Talent for winding wire

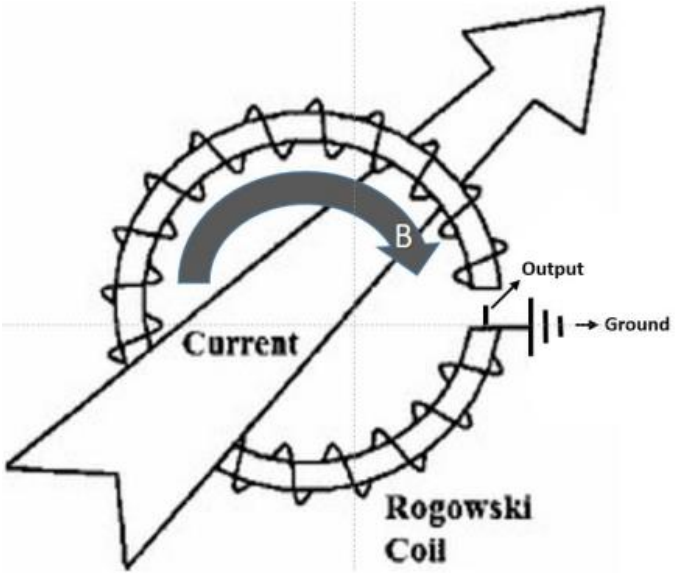
Outline

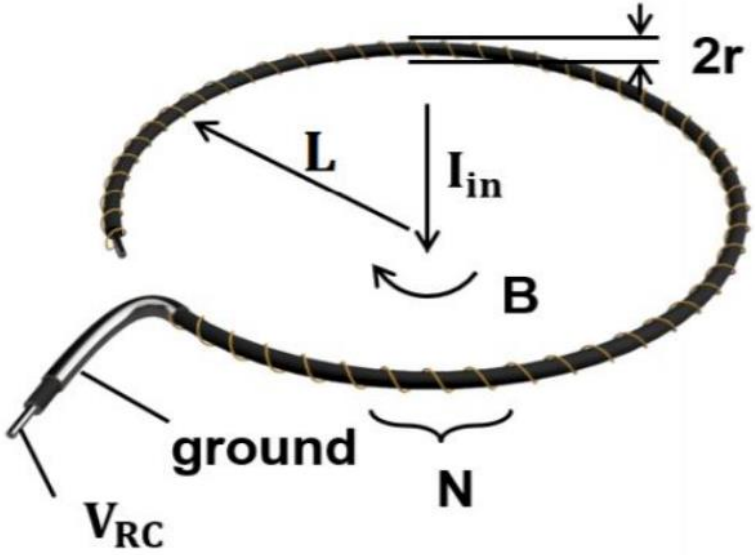
- **Prevention of arcing**
  - **Prevention of Rogowski coil arcing by using heat shrink tubes**
- **Assemble the Rogowski coil with connectors**
  - **Prevention of BNC connector arcing by using heat shrink tubes**
  - **Further insulation from the chamber by using the Kapton and Kapton tape**
- **Install the Rogowski coil to the chamber**
  - **Note: A Kapton slice on the outer disk to prevent the breakdown between the outer disk and the Rogowski coil**

Outline

- **Calibration of the Rogowski coil**
  - **You need to disassemble the capacitor circuit on one side to reduce the peak value by half when use Pearson current monitor to calibration**
- **Previous version vs This version**
- **Improvement direction of Rogowski coil:**
  Replace the BNC connector with the SMA connector
- **Future work**

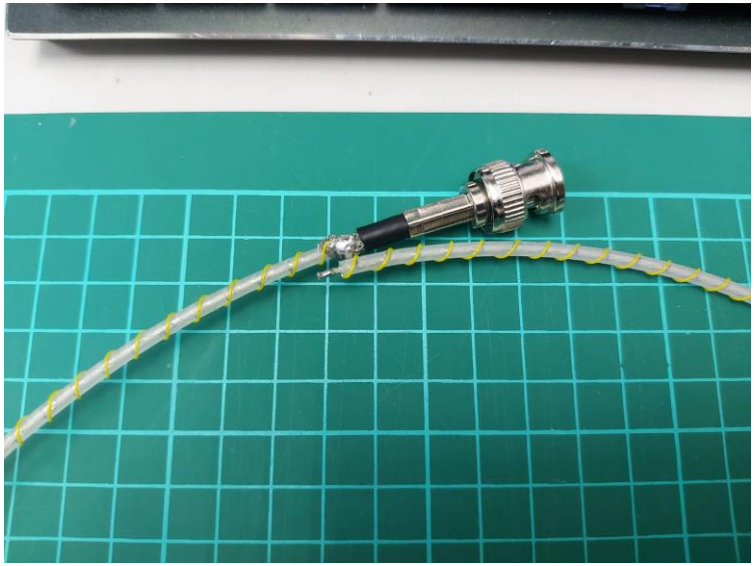
Concept and structure of the Rogowski coil





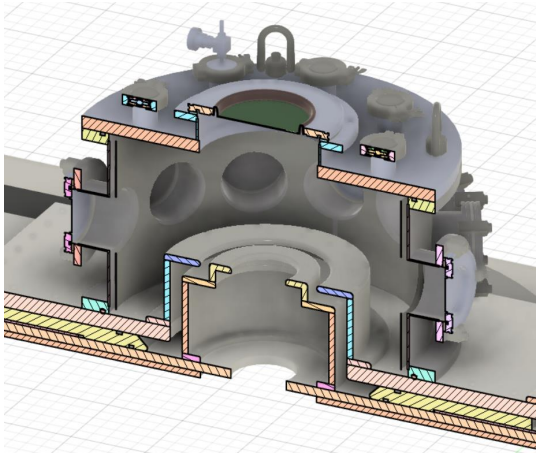
https://capst.ncku.edu.tw/PGS/Student_Thesis/2020_%E8%AC%9D%E7%9F%A5%E5%8F%A1_ncku-109-LA6074033-1.pdf
謝知叡,2020

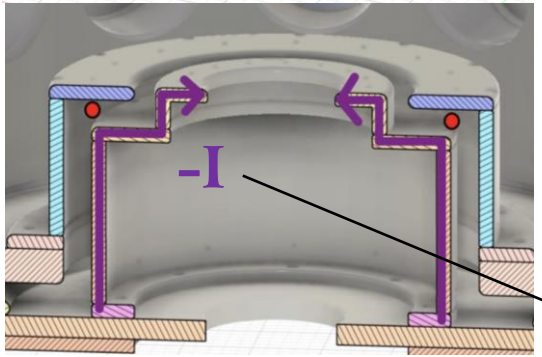
Helical coils must be closed loop

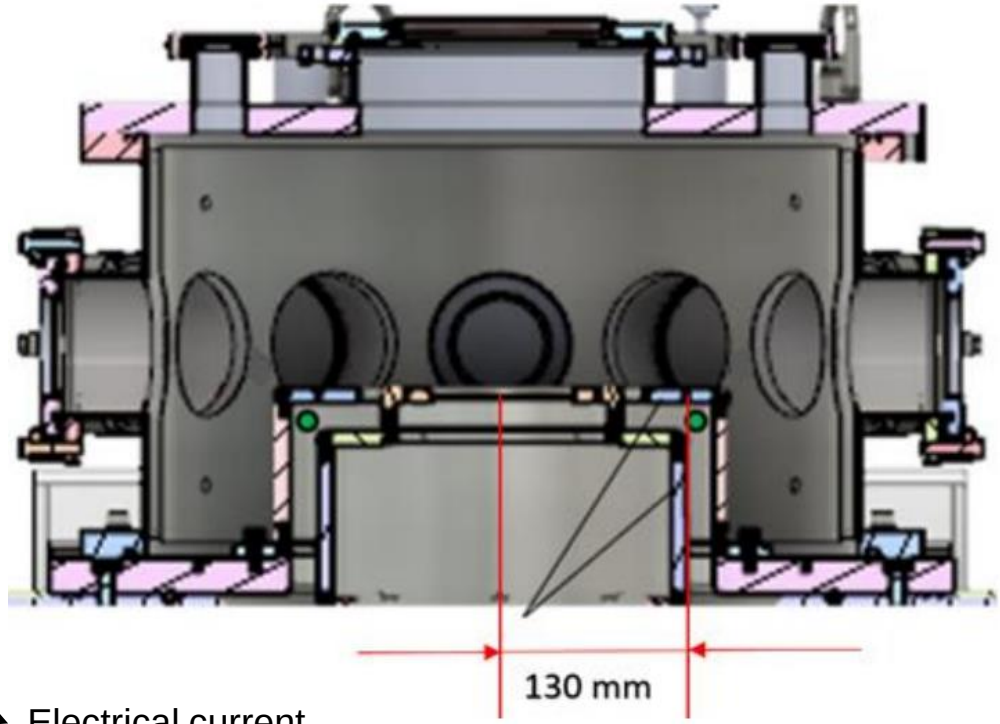


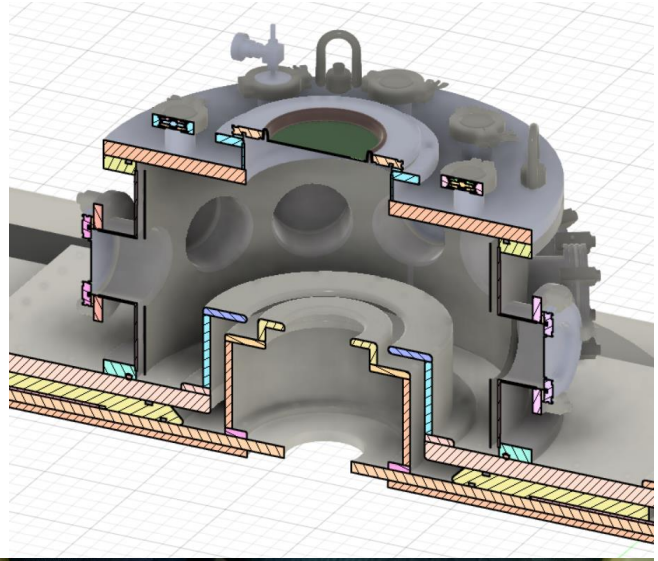
- Helical coils must be closed loop.
- Incomplete closure of the Rogowski coil may cause measurement errors when the input current is not in the center of the Rogowski coil.

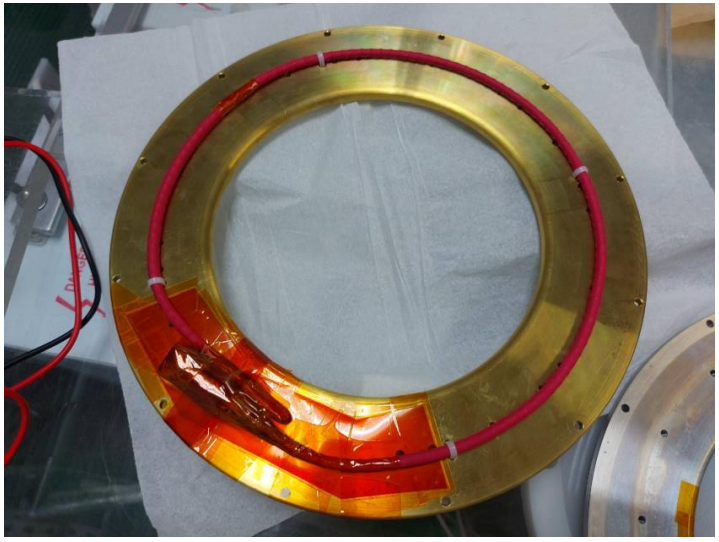
Placement of the Rogowski coil



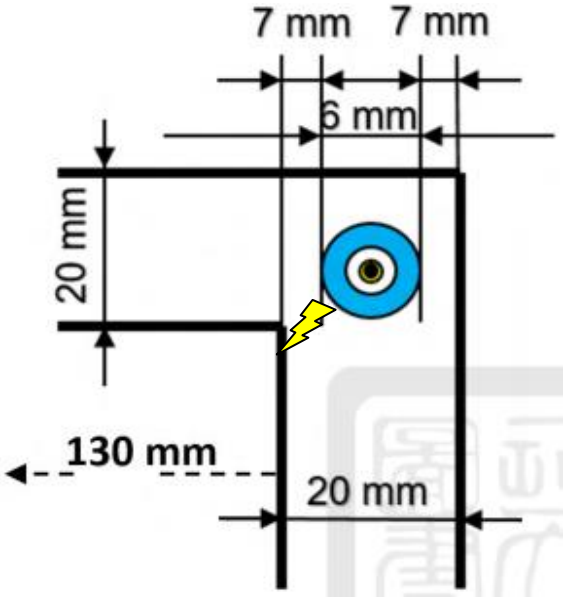


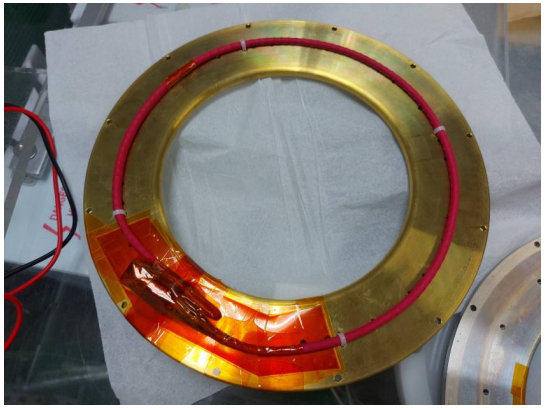






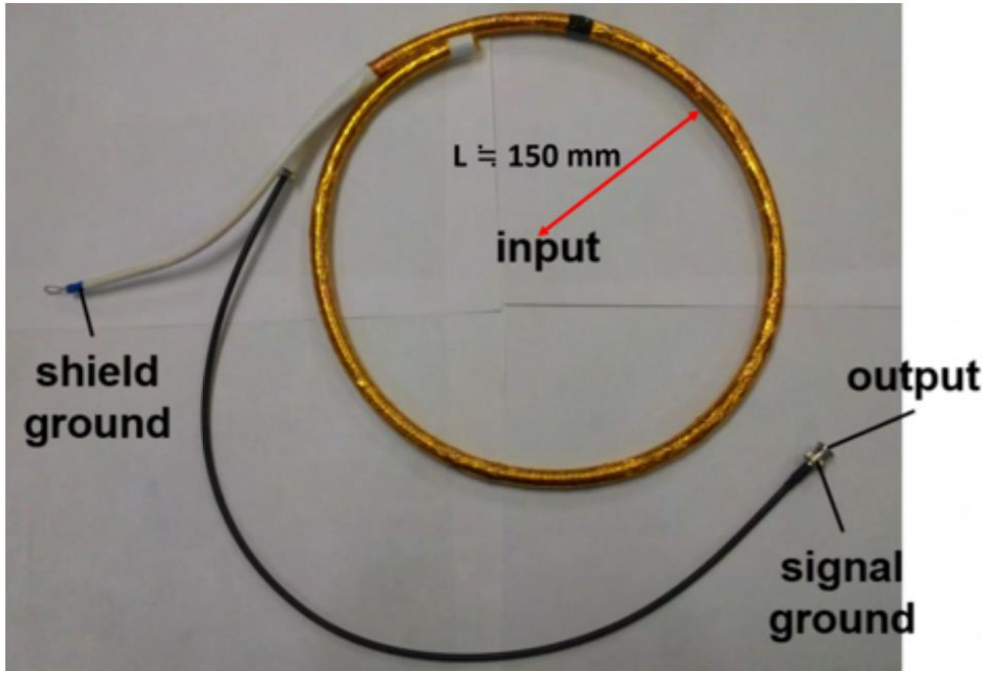
Prevention of arcing

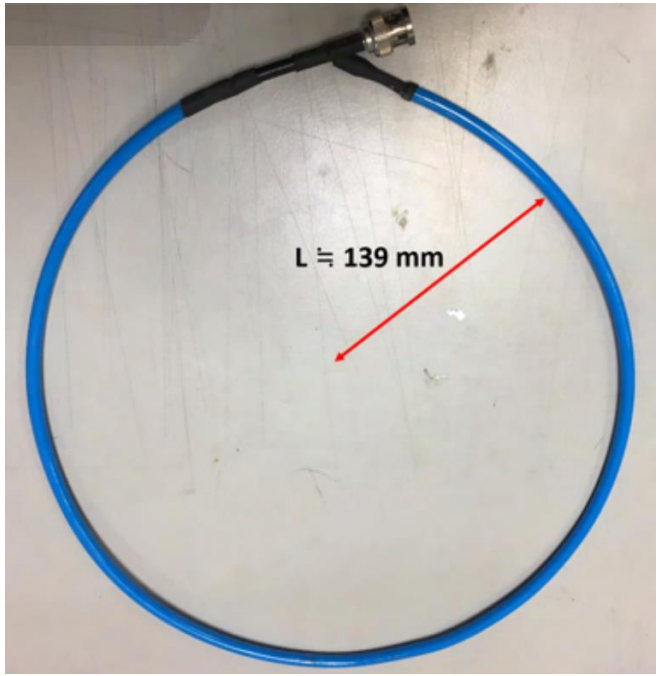




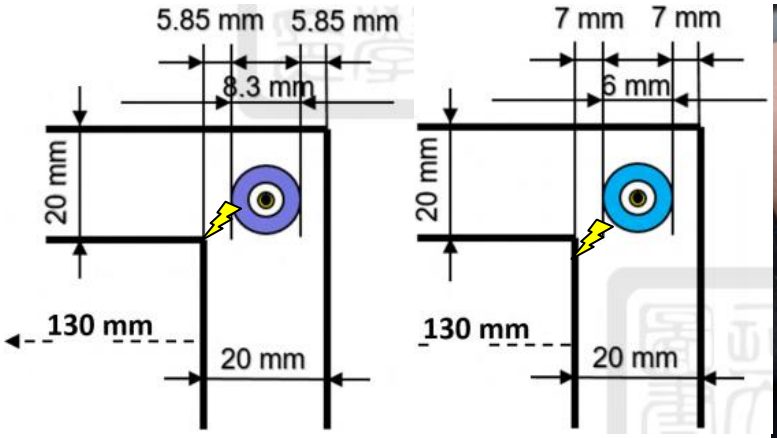
- There are two places where arcing is most likely to occur.
- The first one is the Rogowski coil and the inner disk.
- The second is the Rogowski coil and the outer disk.

The design of the previous two versions

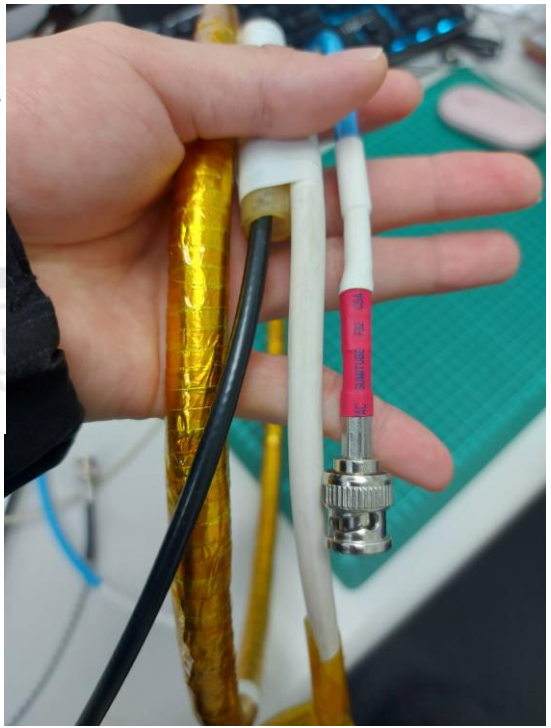




Updating to a thinner Rogowski coil

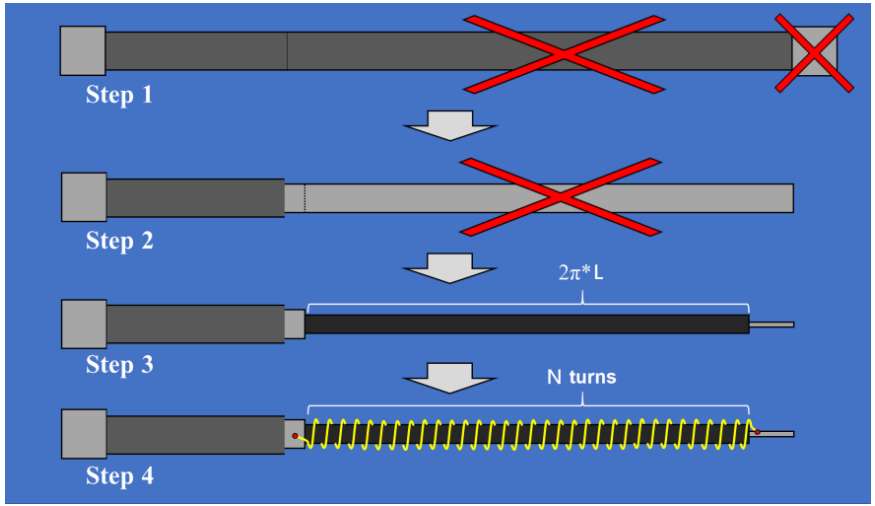


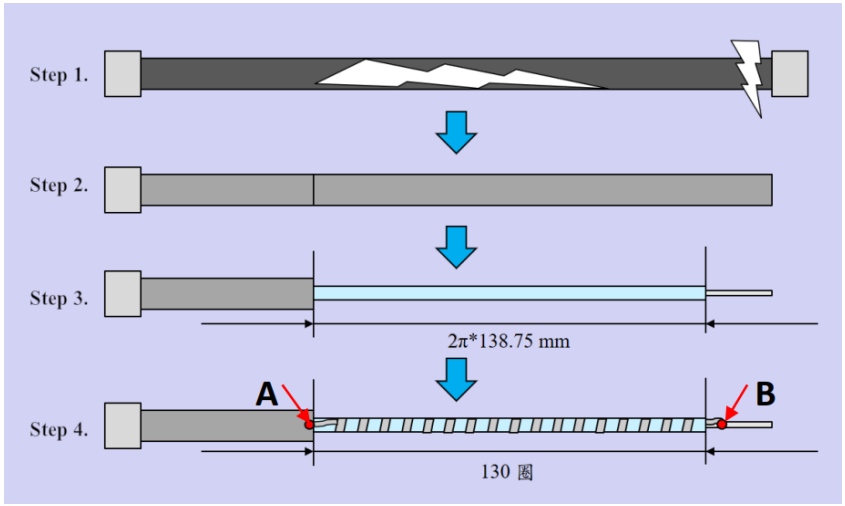
- The thinner Rogowski coil can reduce the possibility of arcing.



- Comparison of actual photos of different Rogowski coils.

Production flowcharts of the previous two versions





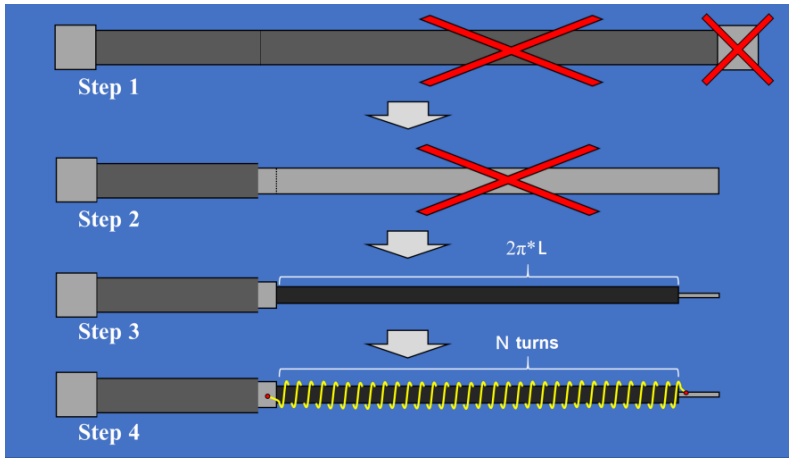
- The differencing process between the previous two versions is that one uses wire winding while the other uses aluminum foil tape winding.
- I used 謝知叡's method(left) to improve the Rogowski coil and make it thinner.

https://capst.ncku.edu.tw/PGS/Student_Thesis/2020_%E8%AC%9D%E7%9F%A5%E5%8F%A1_ncku-109-LA6074033-1.pdf
謝知叡,2020
https://capst.ncku.edu.tw/PGS/Student_Thesis/2022_%E5%8A%89%E5%98%89%E6%A5%B7_ncku-111.pdf
劉嘉楷,2022

Use 謝知叡's version to improve the Rogowski coil

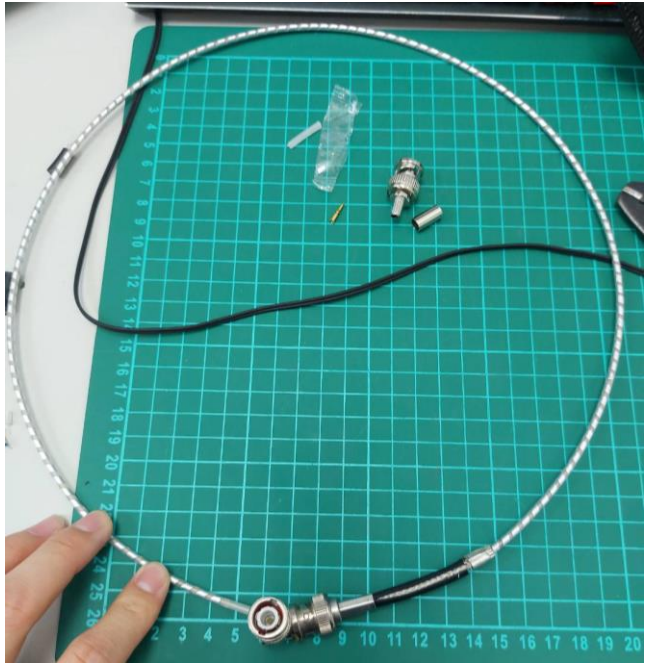
- **Reasons for not using aluminum-platinum tape wrapping**

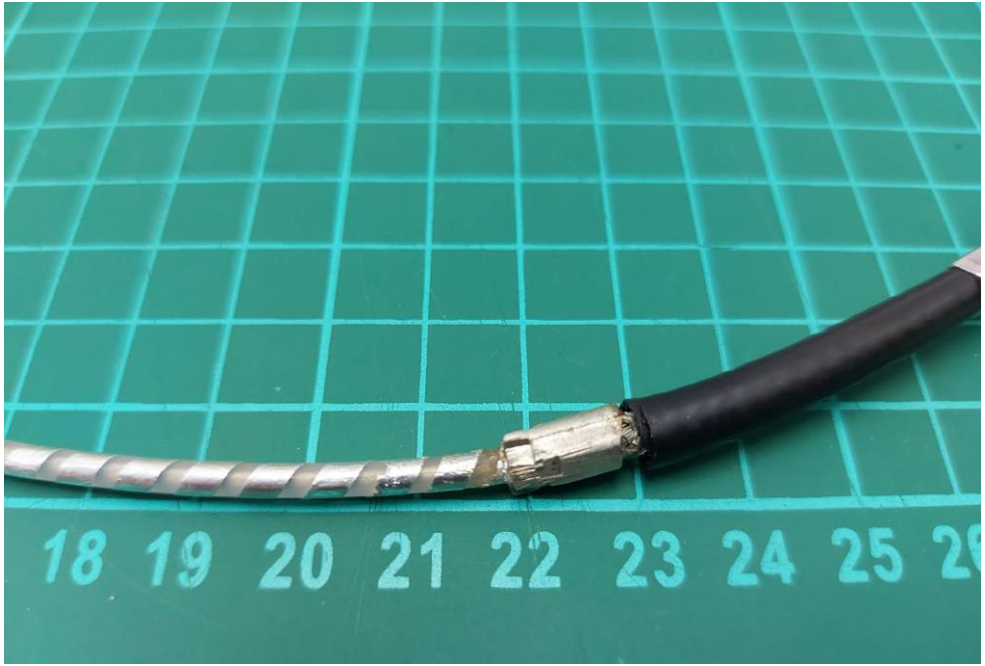
1. **Aluminum foil tape is easy to break and has a high probability of damage.**
2. **The joint between the aluminum foil tape and the coaxial cable is clamped, which is very unstable!**



- 謝知叡's version

嘉楷’s version

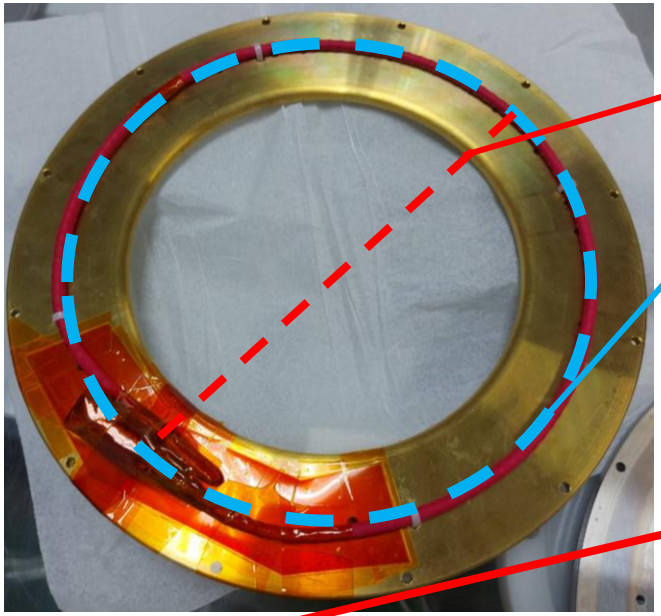




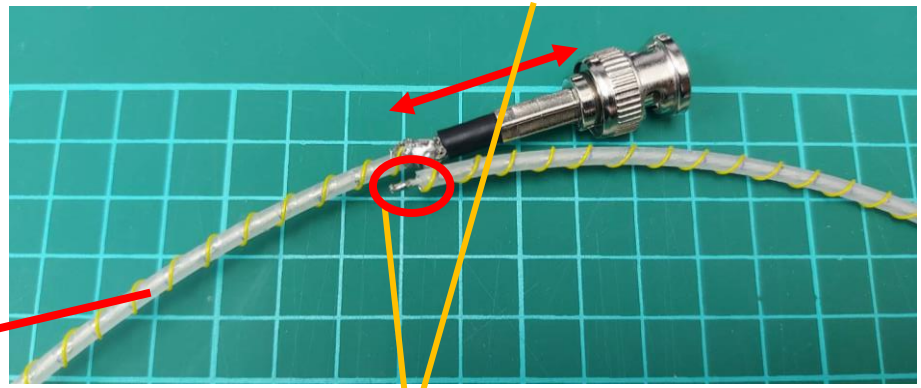
START!!

Required tools for making Rogowski coil

The circumference = 827.8mm, and wrap around the inner insulation layer with ~ 130 turns

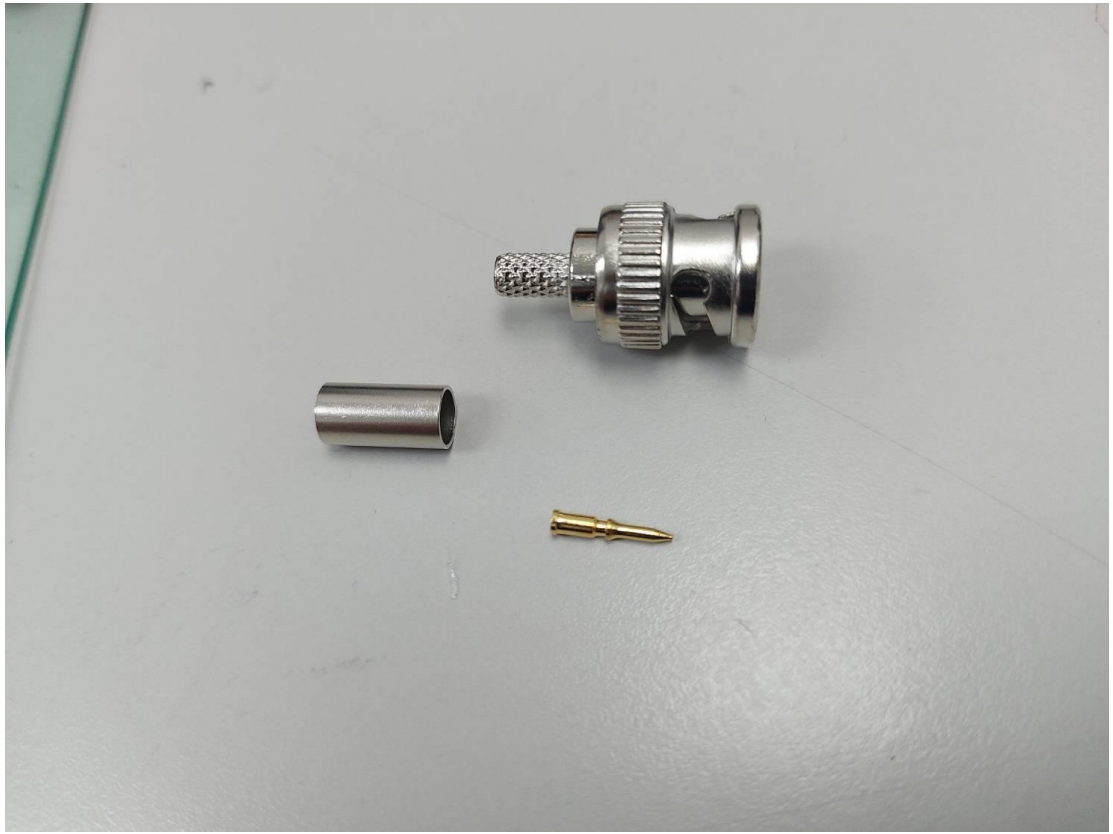


- The diameter(2R) = 263.5mm
- The circumference = 2* π*R = 827.8mm

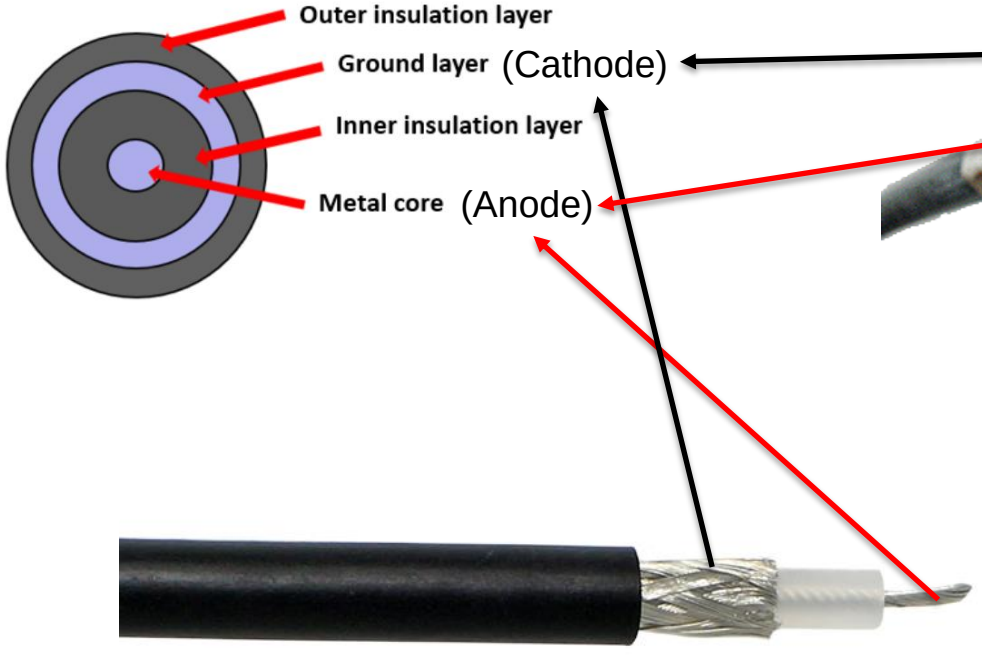


- Wrap around 130 turns to make it dense enough and a large enough voltage to observe.
- **Caution: Some extra length should be reserved here for connecting with connector, and some length should also be left at the end for “soldering”.**

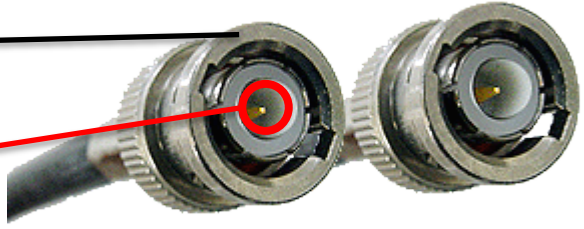
Component of BNC connector



Cross-sectional diagram of a RG-58 coaxial cable



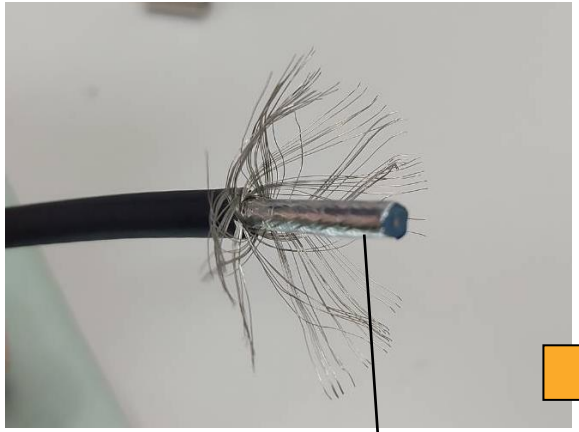
BNC to BNC Cable 50ohm

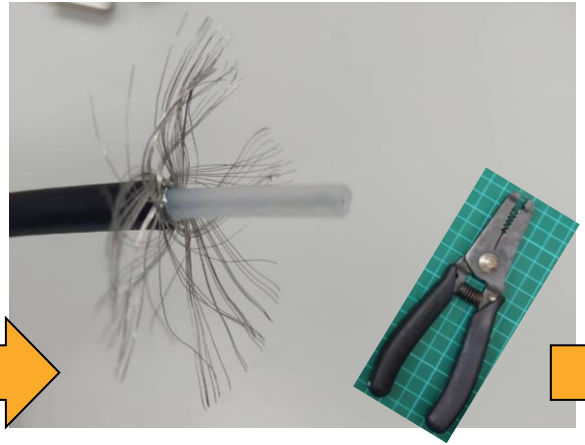


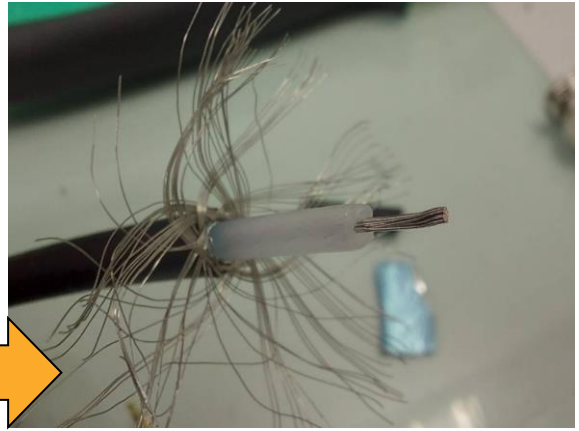
RG-58 Cable

Assembly process of BNC connector and the RG-58 coaxial cable

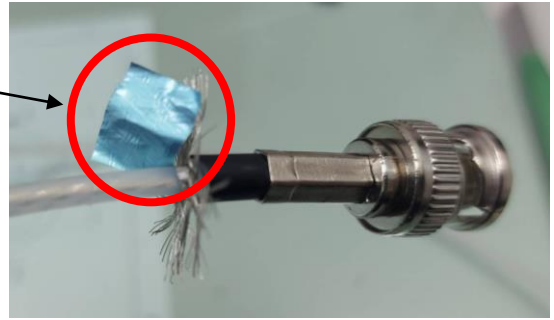
Disassembling the coaxial cable



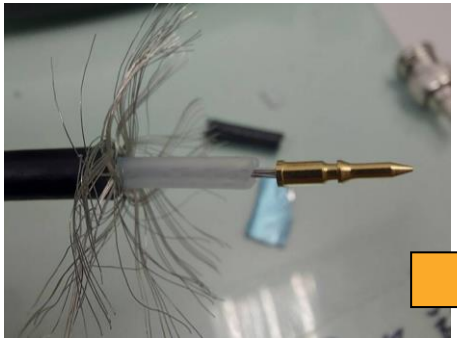


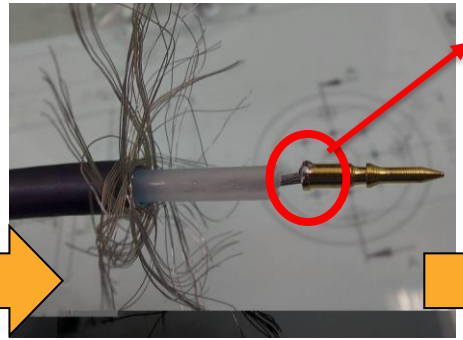


- Note: The back of the aluminum foil(the blue side) is not conductive, it is safer to remove it!

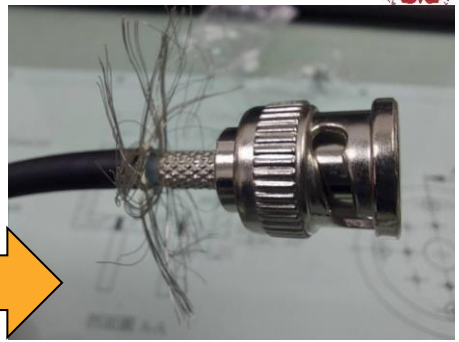


Insertion probe and soldering

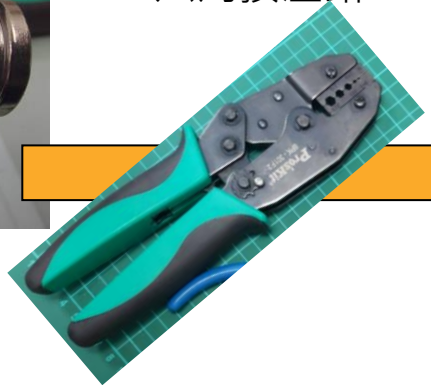


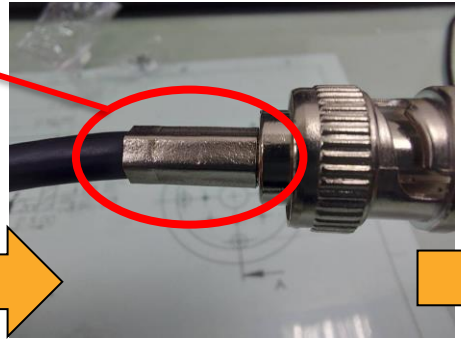


- Solder!
- Or you can use pliers to hold it firmly.



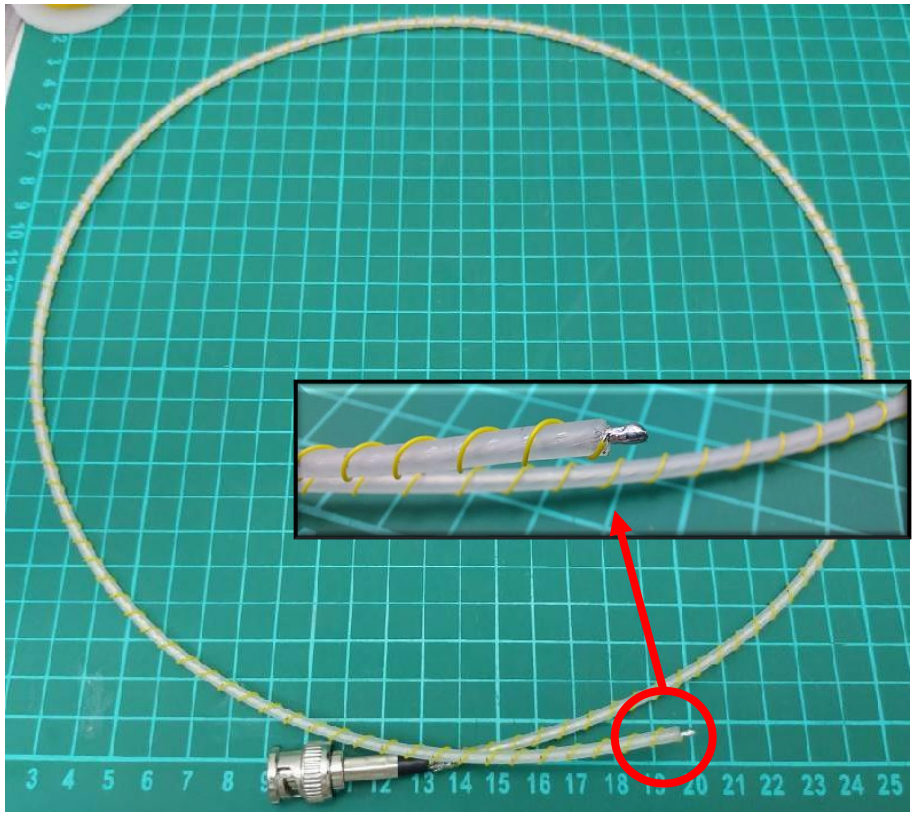
- Clamp with “六角按壓鉗”!

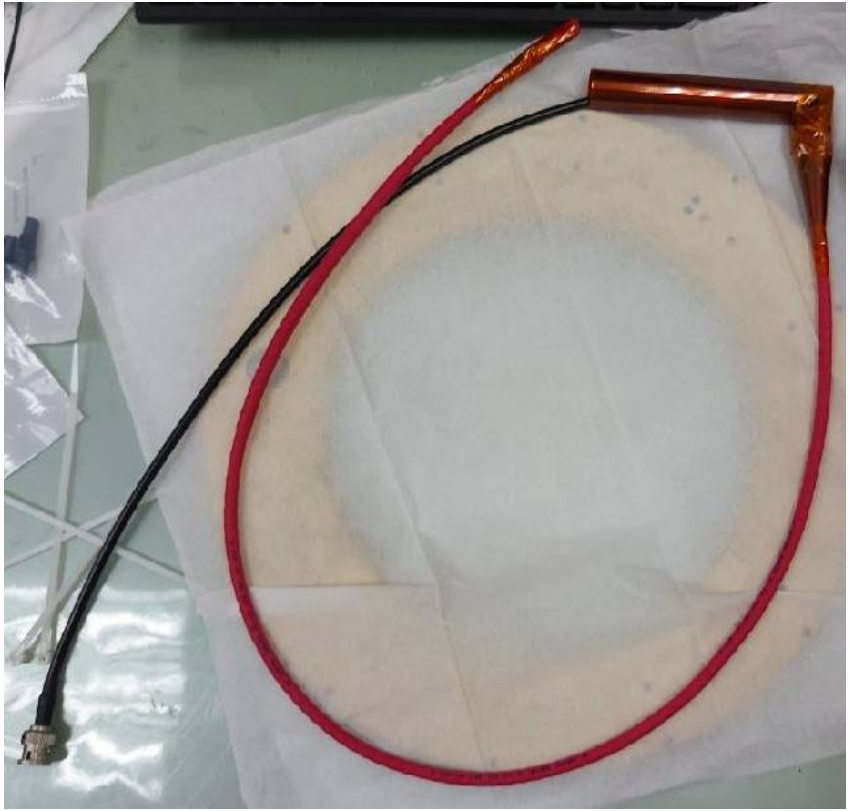




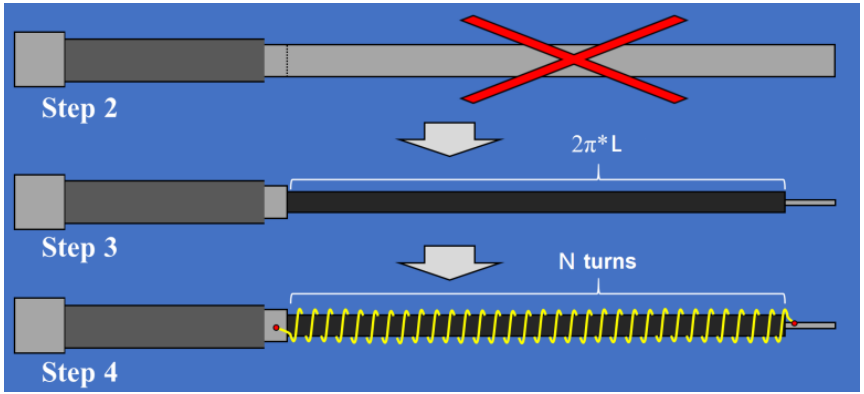
- **Caution: Make sure to check if the wire is conducting electricity!**

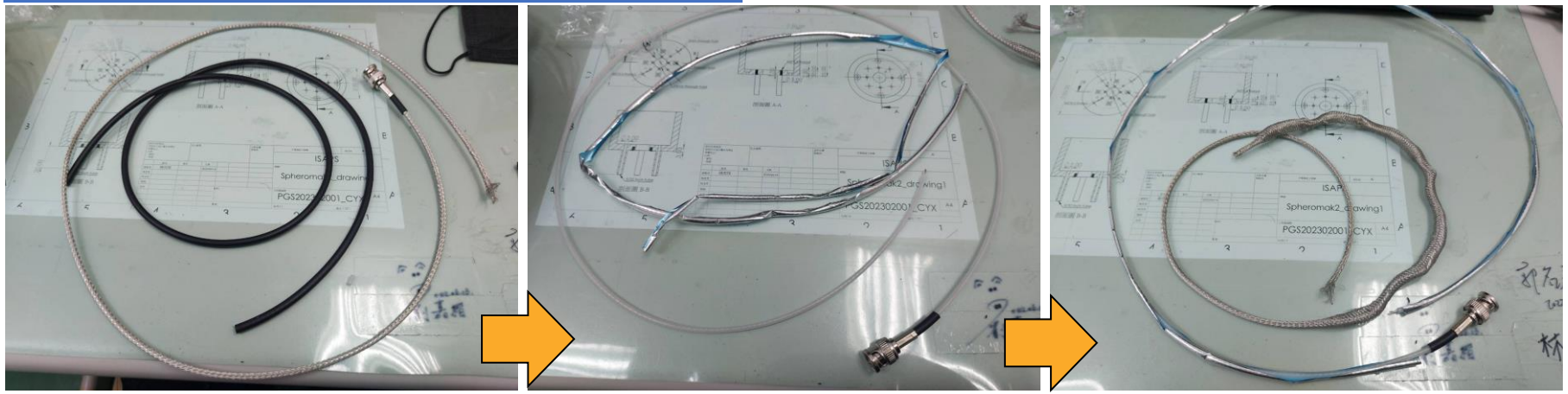
Process of the Rogowski coil



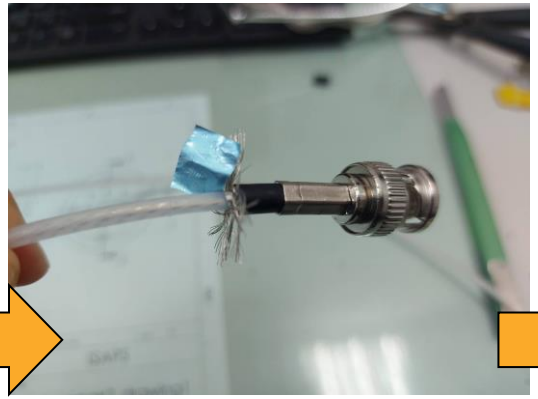


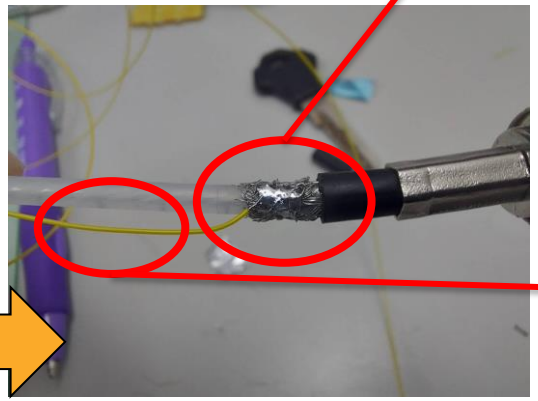
Disassemble the coaxial cable



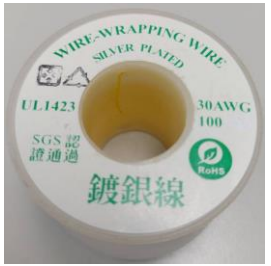


Soldering of the wire and coaxial cable



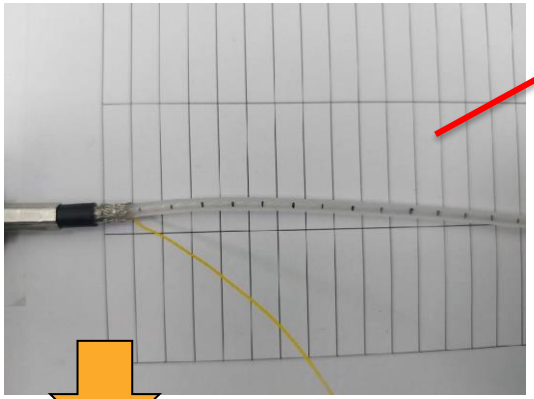


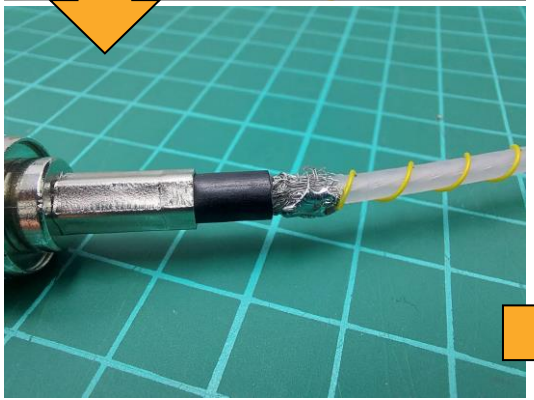
- Solder the thin wire!



- There are no special requirements for the wire, the thinner the better.

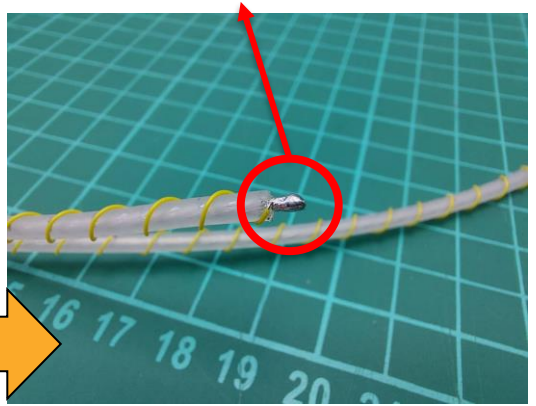
Talent for winding wire, I am a king





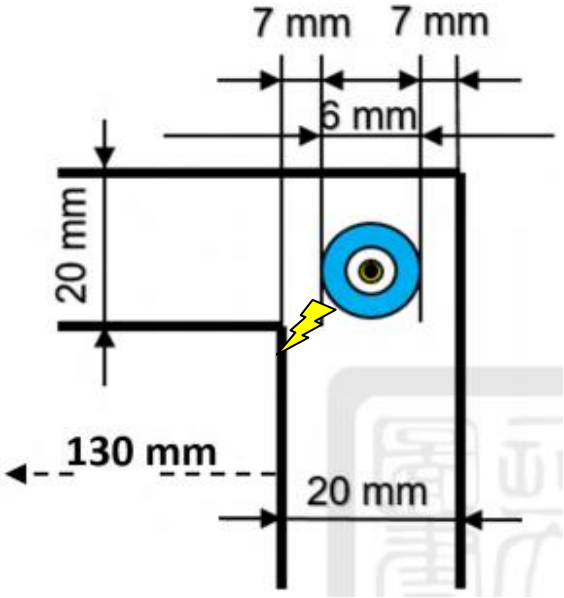
- I made a monospaced label to mark the wire.

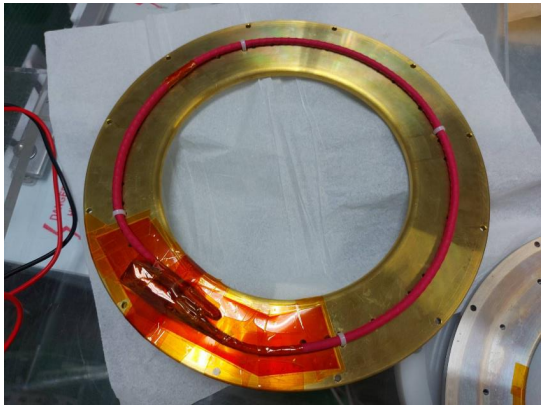
Caution: Be sure to solder without the wires coming loose!



- The internal structure is completed!

Prevention of arcing



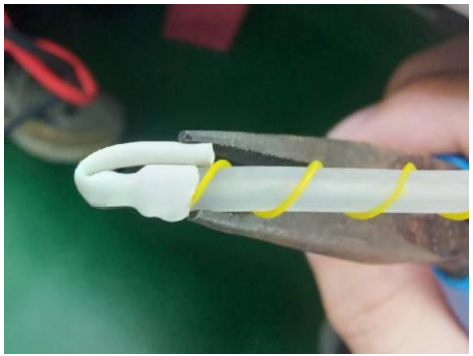


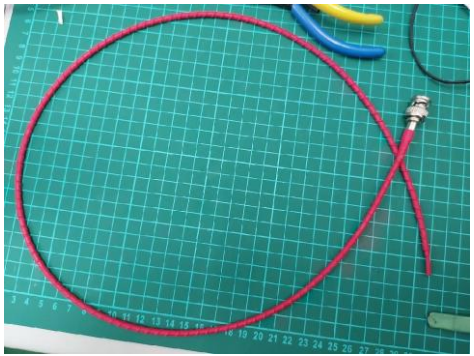
- There are two places where arcing is most likely to occur.

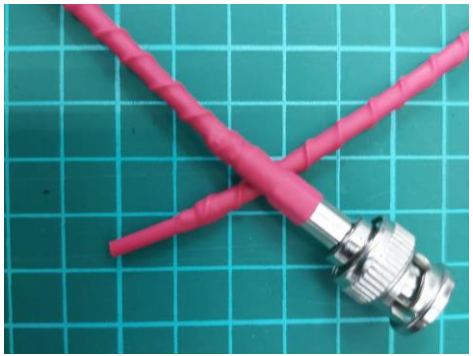
1. The first one is the Rogowski coil and the inner disk.
2. The second is the Rogowski coil and the outer disk.

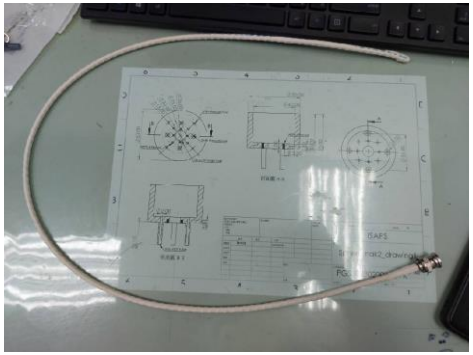
Prevention of Rogowski coil arcing by using heat shrink tubes

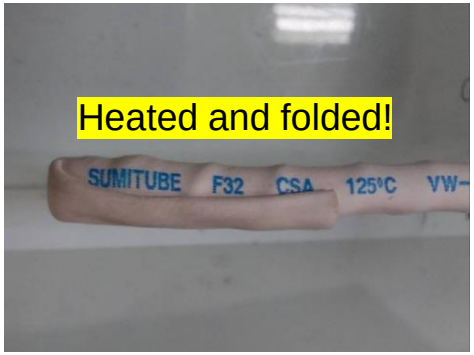
- It is necessary to protect wires from current penetration caused by the system's high voltage.









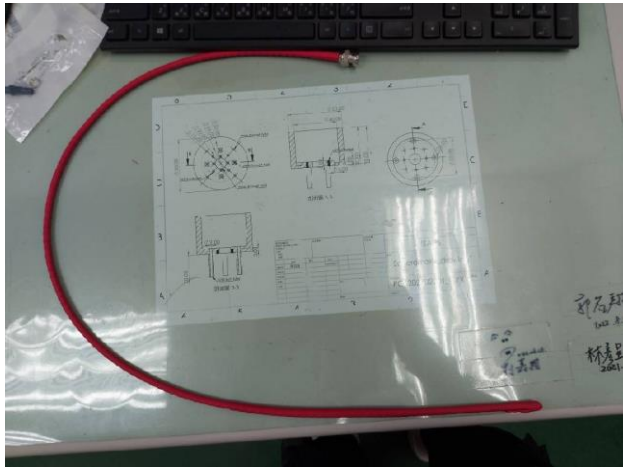


- Just put on the appropriate heat shrink tubing (熱縮套管).
- Wrap the tail first.
  The excess length can be heated with a hot air gun(熱風槍) to make it soft, and then folded and pasted.

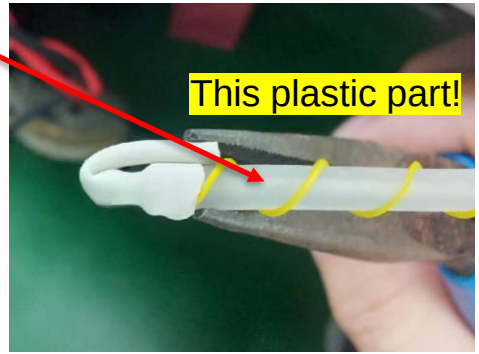
Prevention of Rogowski coil arcing by using heat shrink tubes

Caution:

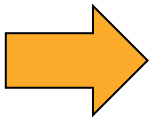
- **Since the heated heat shrink tube is very hot, gloves should be worn when handling it.**
- **When using a hot air gun, the plastic insulation layer of the cable's inner wire will soften due to the high temperature. Be careful not to press it to avoid conduction.**



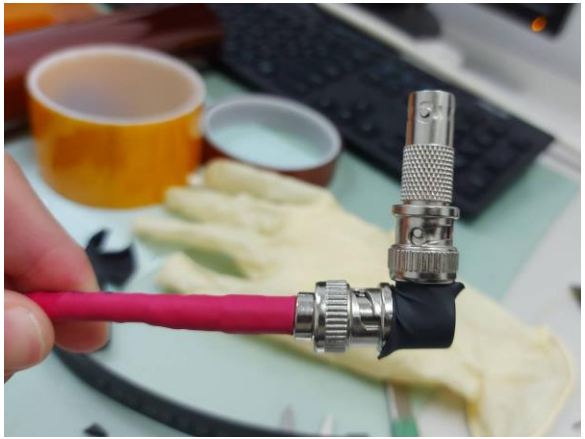
- The third layer of heat shrink tubing.
- Then the heat shrink tubes are partially completed.



Assemble the Rogowski coil with connectors



Prevention of BNC connector arcing by using heat shrink tubes

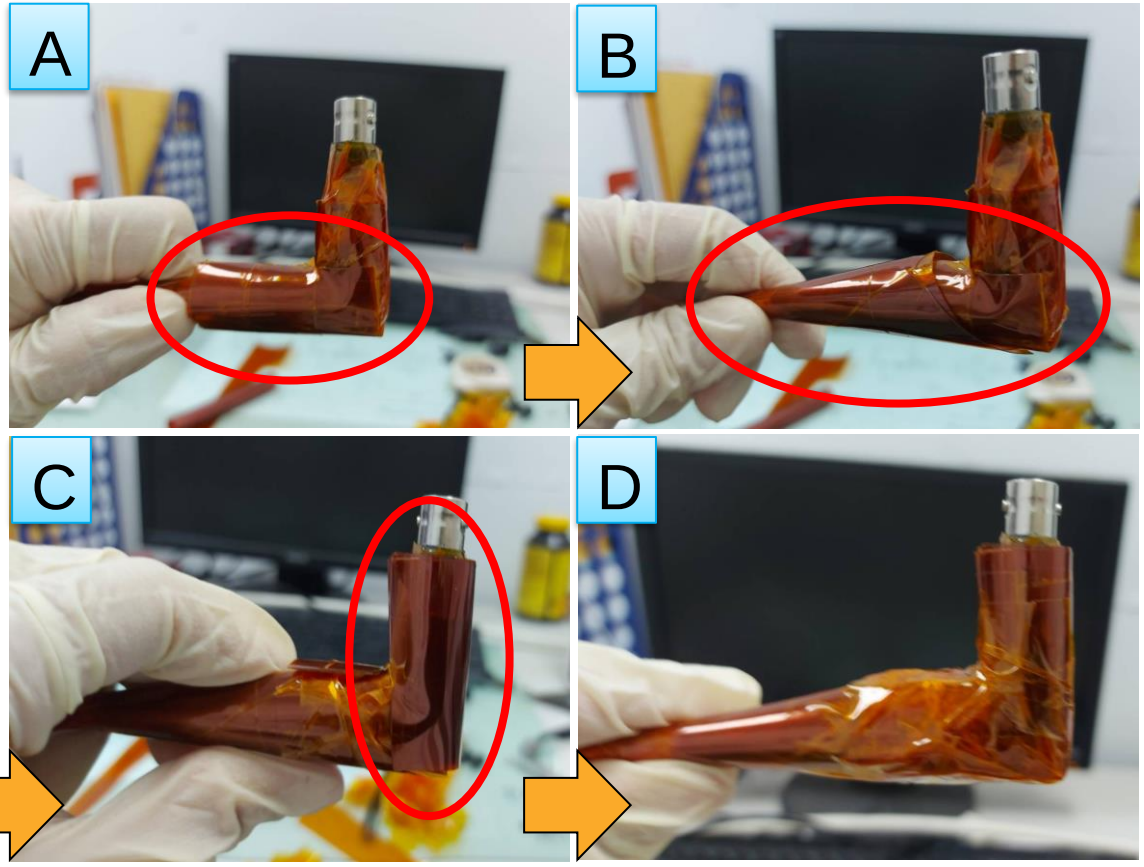


Note: Cutting the heat shrink into a “circular sector shape” will allow you to fit the heat shrink into the BNC connector better.

Further insulation from the chamber by using the Kapton tape

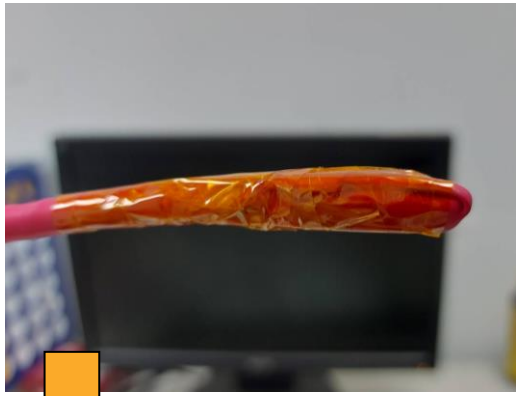
- This fills the gap between the heat shrink tube on the connector and the heat shrink tube on the wire.

Further insulation from the chamber by using the Kapton and Kapton tape

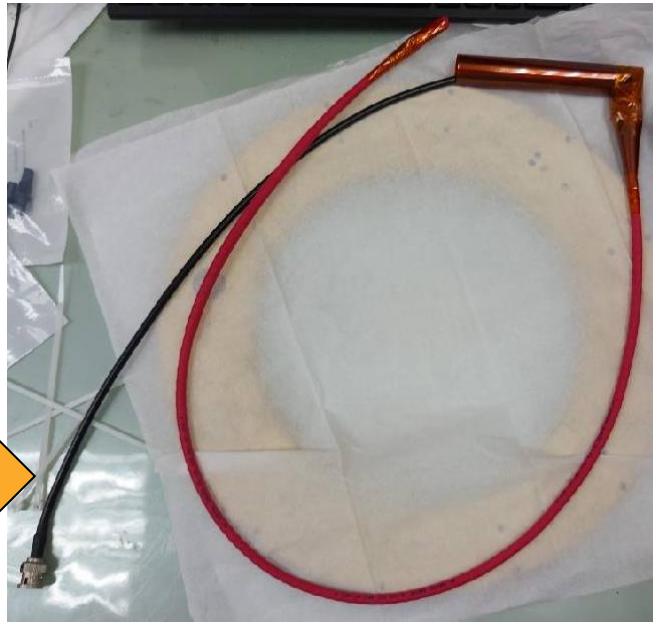


- A: Cut the Kapton into a cylindrical shape to the BNC connector.
- B: Cut the Kapton into a cone shape to protect the gap between the Rogowski coil and the BNC connector.
- C: Same as picture A to protect the connector.
- D: Wrapping the Kapton tape to fill the gap.

Further insulation from the chamber by using the Kapton and Kapton tape

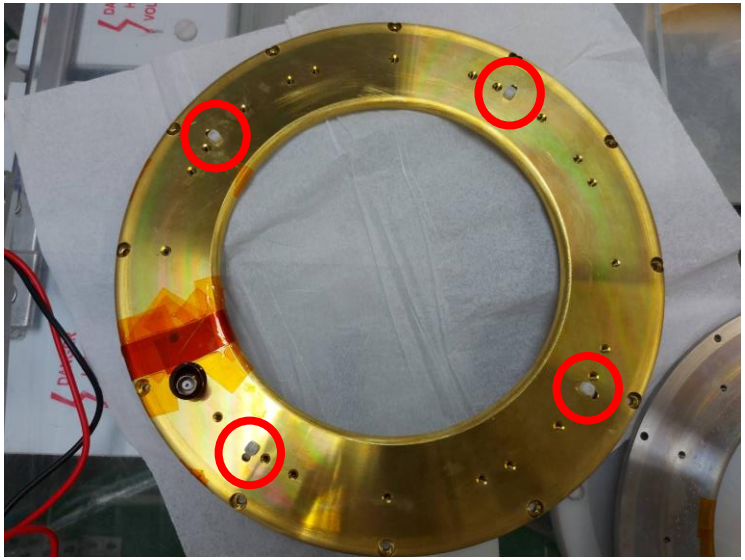


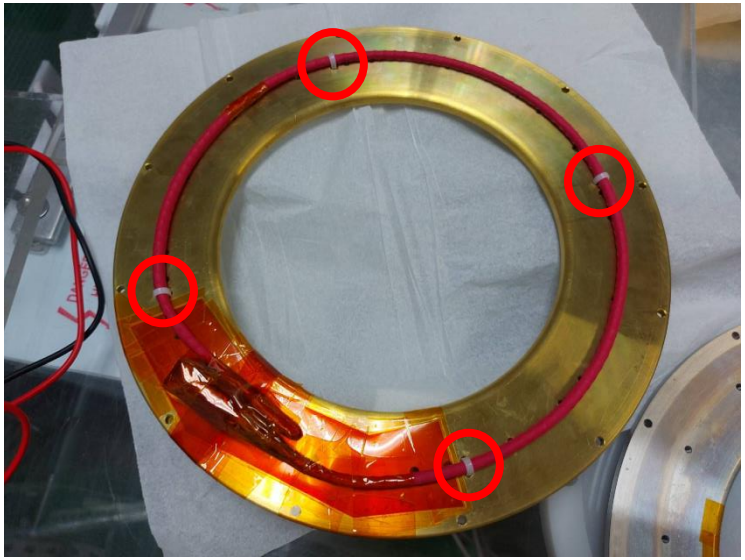
- Use the Kapton tape to wrap the Rogowski coil's tail too.
- Cut the Kapton into a cylindrical shape to put it over the connector.
- Then we finish it all!



- **Caution: Make sure to check if the Rogowski coil is conducting electricity!**

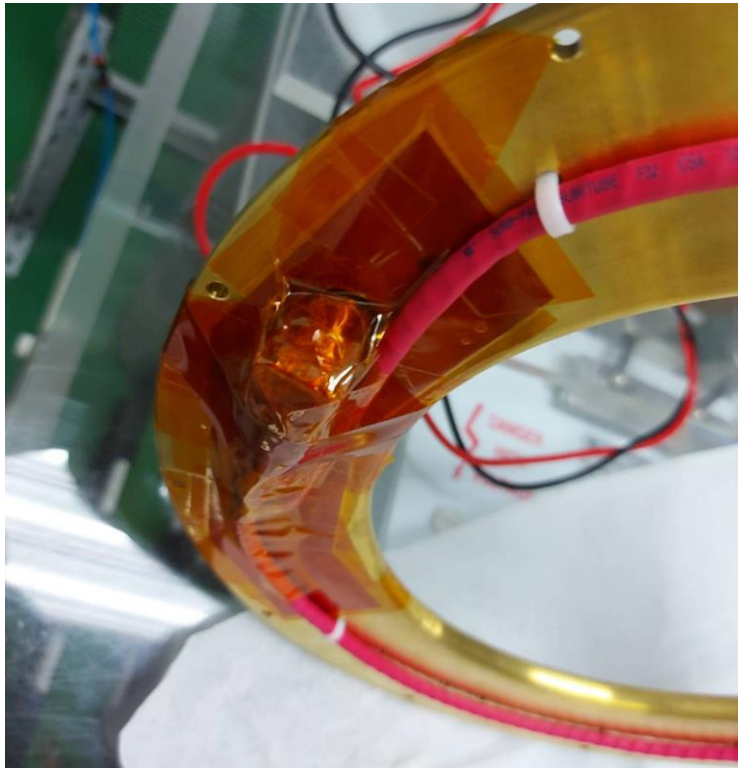
Install the Rogowski coil to the chamber



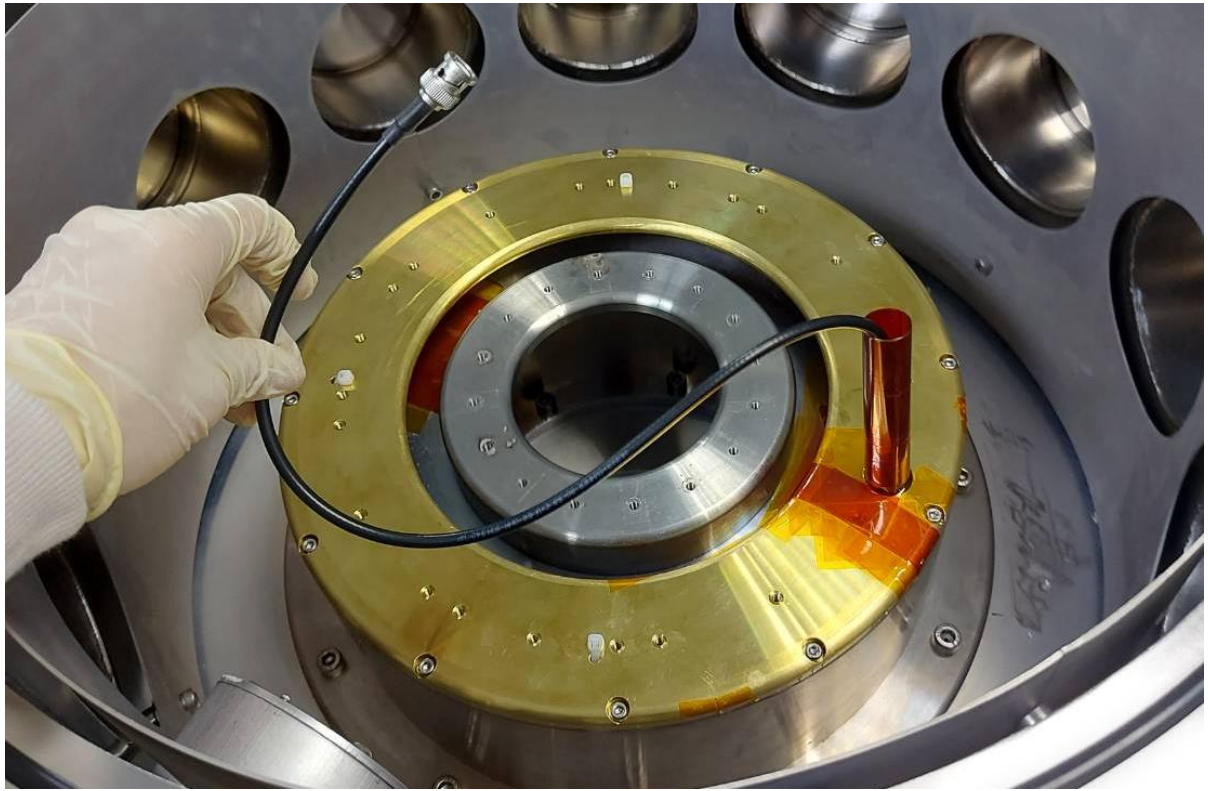


- Align the Rogowski coil with the holes(Circled in the picture) in the plate and tie them with cable ties(束線帶).
- Apply Kapton tape to secure.

Note: A Kapton slice on the outer disk to prevent the breakdown between the outer disk and the Rogowski coil



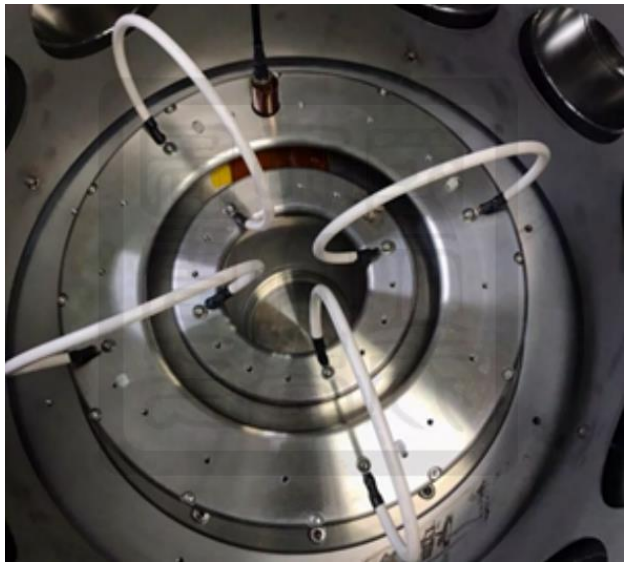
I am a king

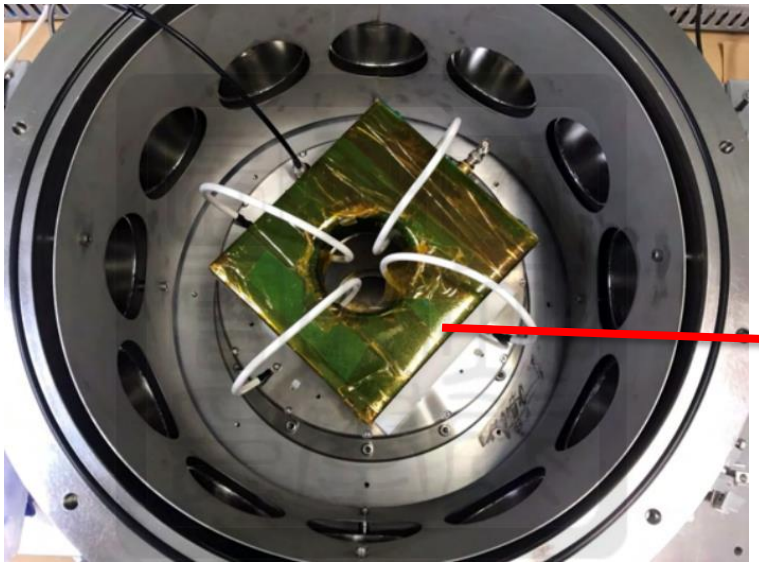


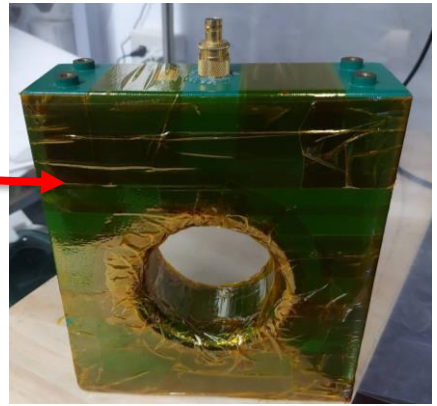
- **Caution: Make sure to check if the Rogowski coil is conducting electricity!**

Calibration of the Rogowski coil

- The Rogowski coil was calibration with the Pearson current monitor.

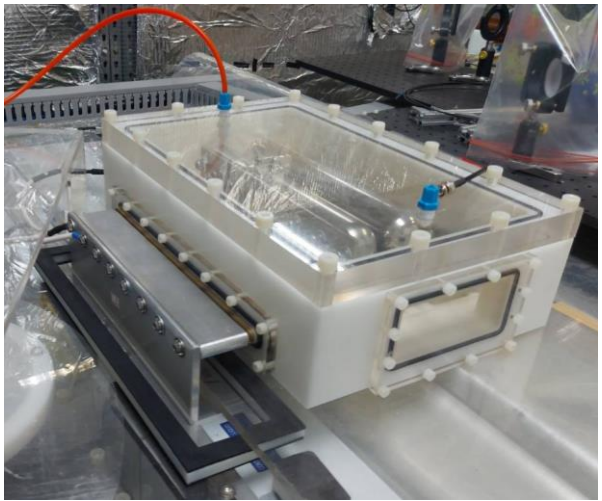






You need to disassemble the capacitor circuit on one side to reduce the peak value by half when use Pearson current monitor to calibration

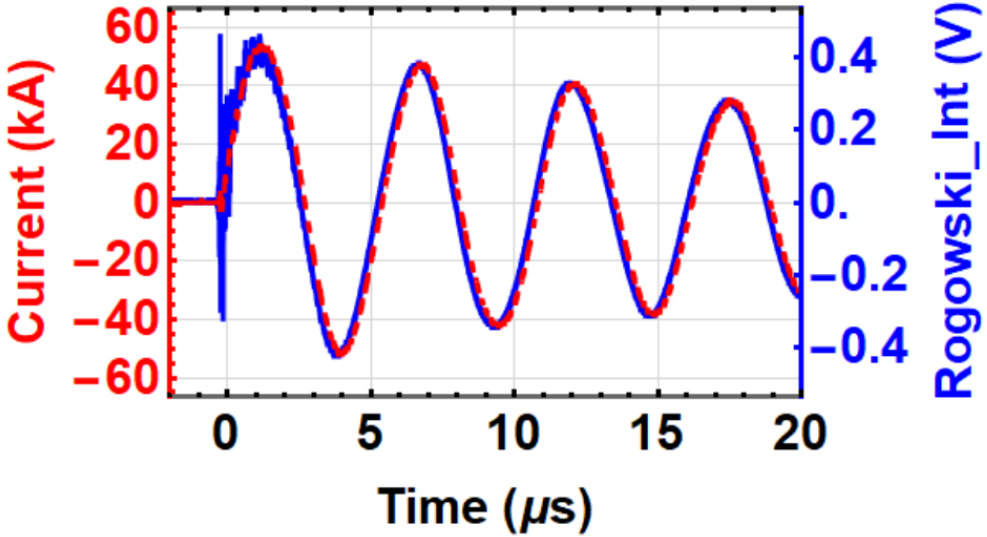
- The “voltage measured” by the Rogowski coil will be proportional to the “correct current”, we use Pearson current monitor(correct current) for comparison.
- But!! The maximum current measured by Pearson current monitor is 50kA(safety current), so we need to disassemble the capacitor circuit on one side to reduce the peak value by half.



Remove the screws to disassemble the transmission plate between the capacitor and the chamber.

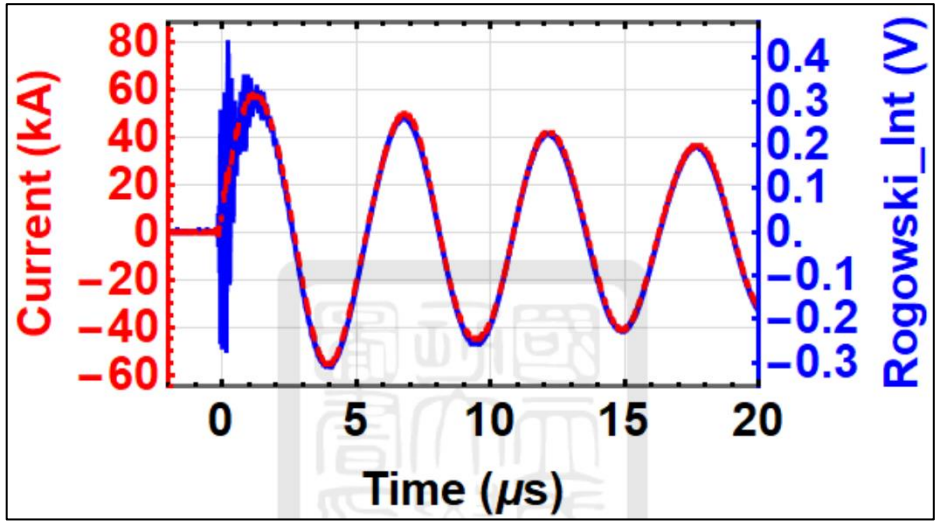
I(kA) = (123.5 ± 0.8)*V_Rog_Int(V)
The time delay(drift time) = -138 ± 2 ns

- Conduct a system discharge test to obtain 10 sets of data, and then calculate the average as a calibration.
- The capacitor of the PPS on one side must be removed because the maximum current of the Pearson current monitor is 50kA.

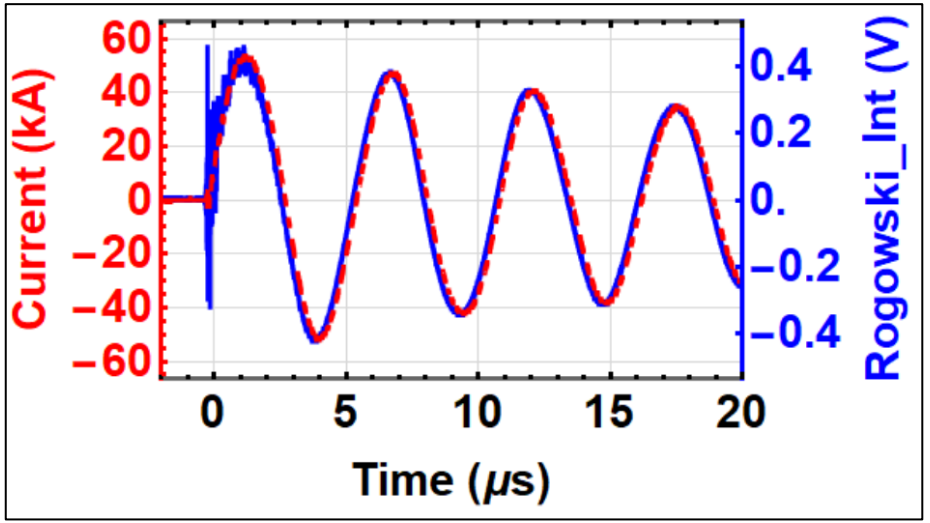


- I(kA) = (123.5 ± 0.8)*V_Rog_Int(V)
- The result has a drift, the time delay = -138 ± 2 ns.

Previous version vs This version



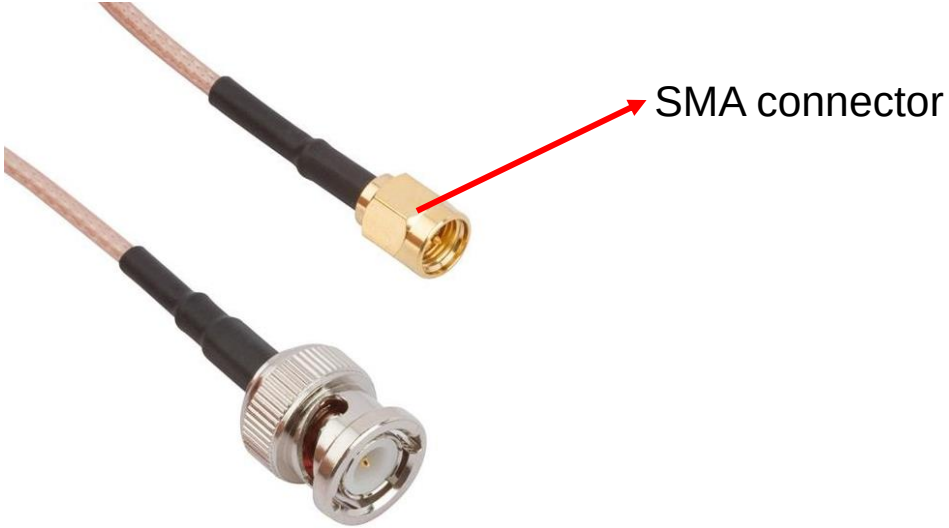
- 嘉楷's version



- My version

Improvement direction of Rogowski coil: Replace the BNC connector with the SMA connector

- To improve the Rogowski coil, we can consider replacing BNC connectors with SMA connectors(thinner connectors).
- Paste Kapton tape and Kapton on the anode and the cathode(Coaxial-transmission line, the inner and outer disk) inside the chamber.



Future work

- Keep doing the flyer plate exp. to gather more data.
- Update the discharge operation procedure of pulsed-power generator.

Summary

The third version of the Rogowski coil is finally completed

- I(kA) = (123.5 ± 0.8)*V_Rog_Int(V)
- The calibration is done, time delay = -138 ± 2 ns.