Kyoto University Nuclear Reactor FFAG Accelerator

Development of charge-exchange foil

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CONTENTS

BACKGROUND

KURRI improve experimental efficiency of accelerator Driven Subcritical Reactor(ADSR)

- increase intensity of the beam in Kyoto University FFAG accelerator

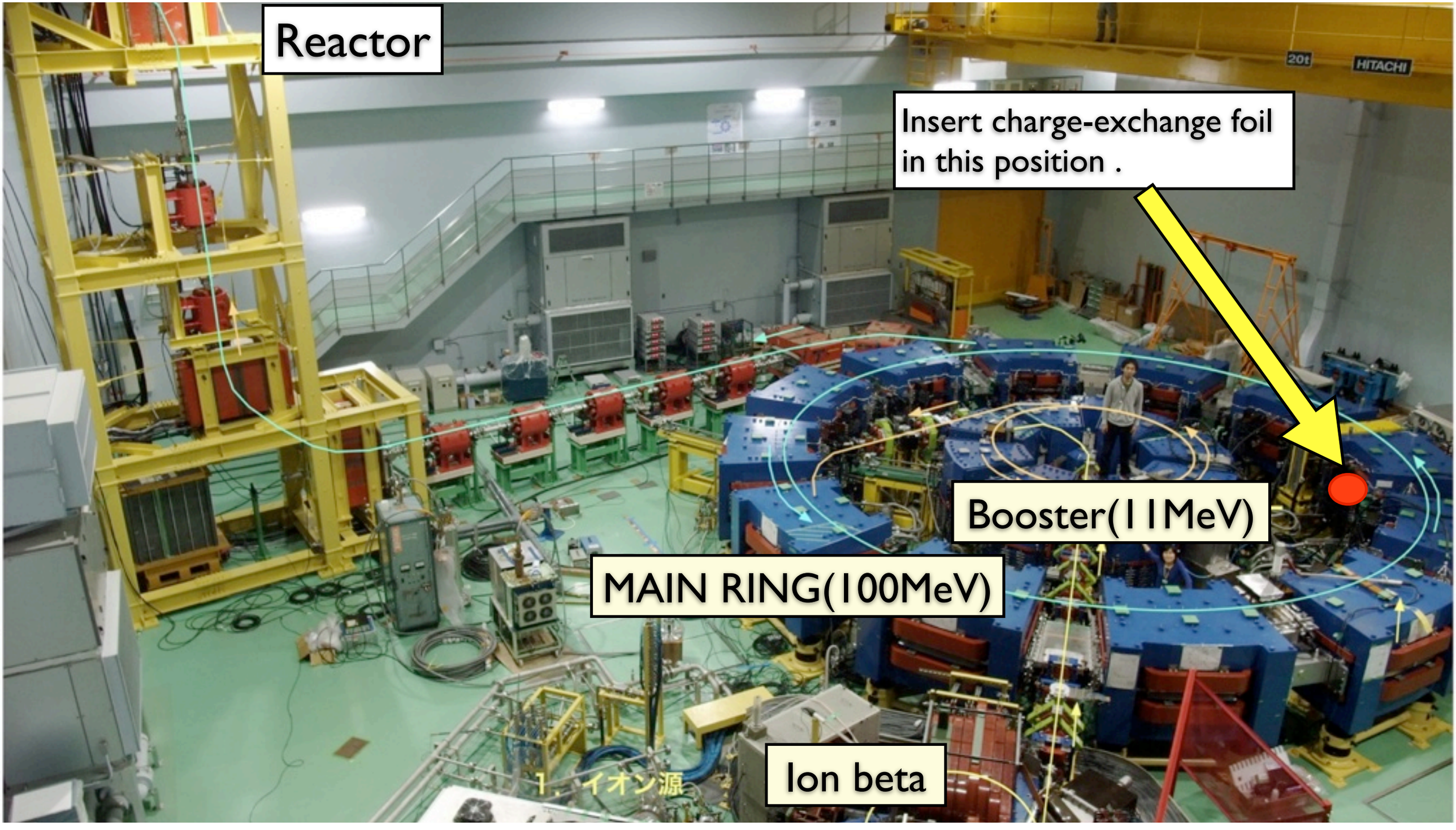
Way to increase intensity of the beam

- injection system adopt to H^- charge-exchange injection
- injection accelerator change LINAC from Booster

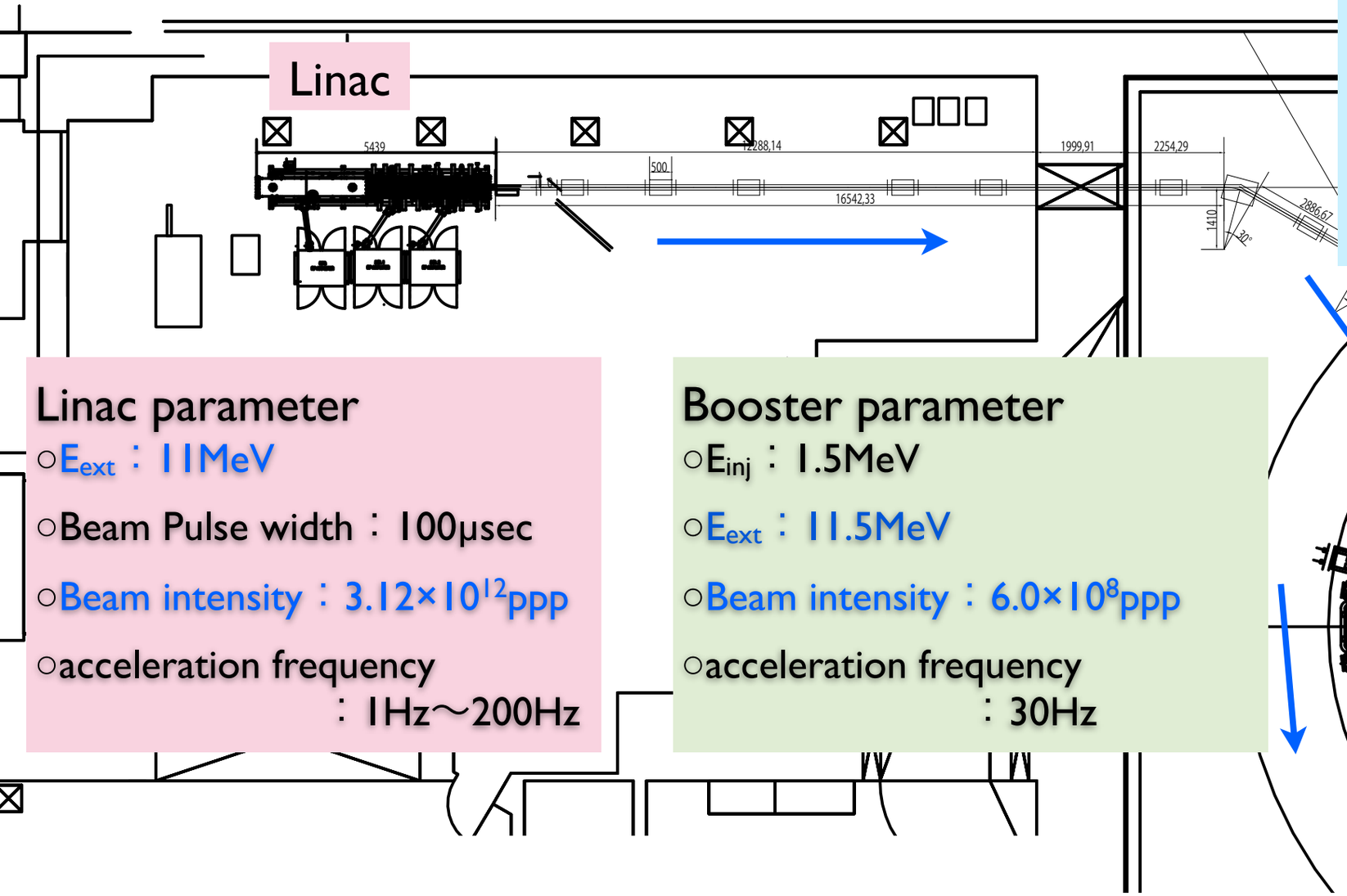
design of charge-exchange foil

It is necessary to success H^- charge-exchange injection

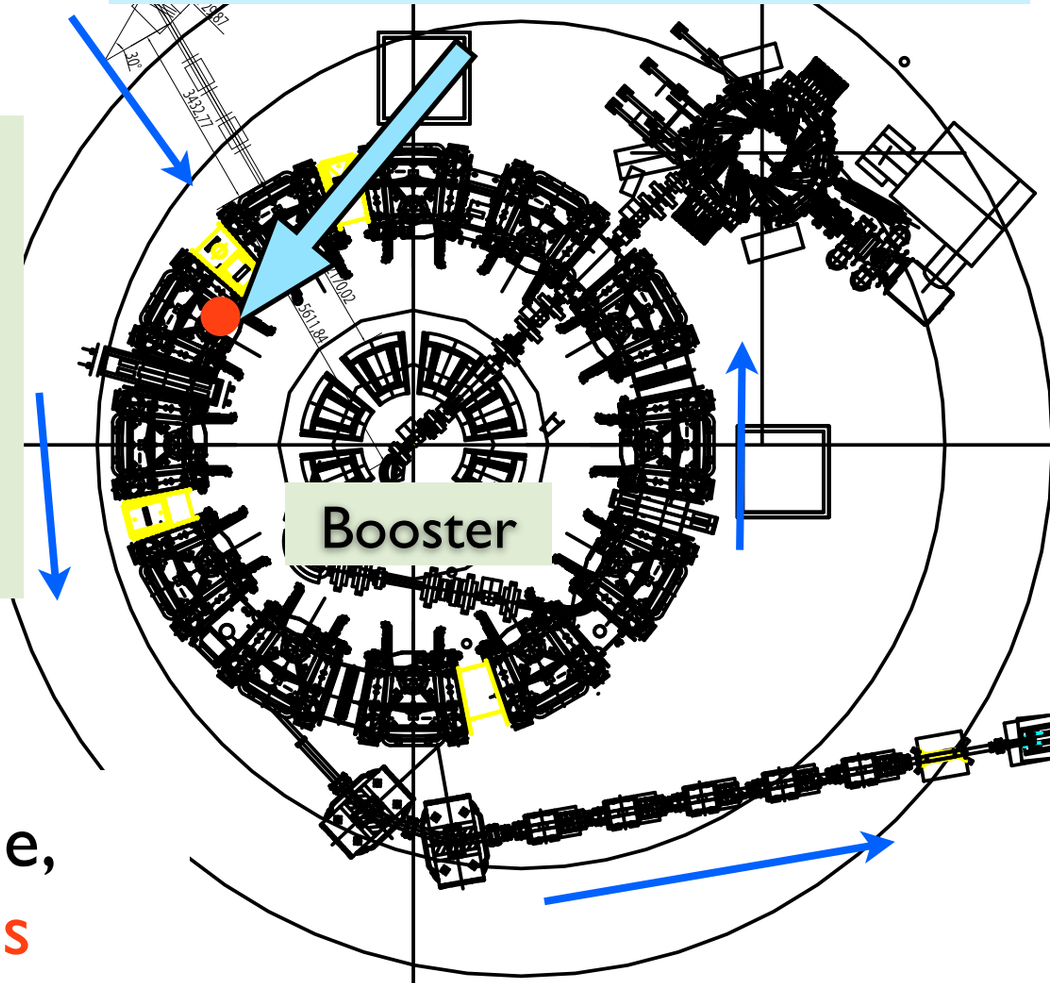
Layout of the Kyoto university FFAG accelerator system



Upgrade of Kyoto university FFAG accelerator



The position of charge-exchange injection
(Charge-exchange foil insert from inside MAIN RING)



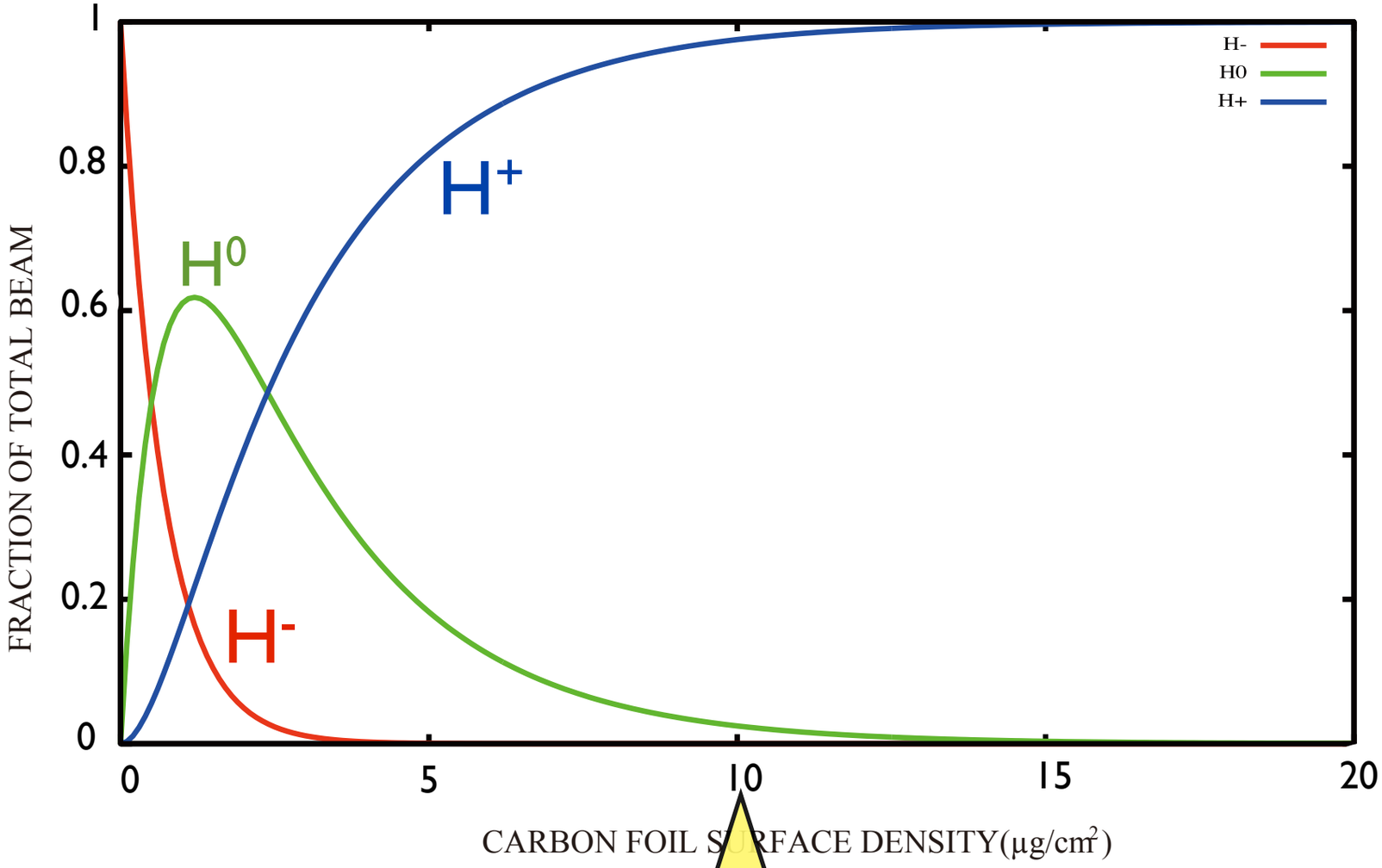
Linac parameter
- ○E_{ext} : 11MeV
- ○Beam Pulse width : 100μsec
- ○Beam intensity : 3.12×10^{12}ppp
- ○acceleration frequency : 1Hz～200Hz

Booster parameter
- ○E_{inj} : 1.5MeV
- ○E_{ext} : 11.5MeV
- ○Beam intensity : 6.0×10^{8}ppp
- ○acceleration frequency : 30Hz

The energy of Linac and Booster are almost same,
but beam intensity of Linac has higher 1000 times than it of Booster.

Charge-exchange efficiency

Material of charge-exchange foil is made of carbon.
Because carbon is cheap and easy to make.



Thickness of carbon foil	charge-exchange efficiency(%)
5μg/cm²	81.7%
10μg/cm²	97.5%
15μg/cm²	99.6%
20μg/cm²	99.9%

Figure1 charge-exchange efficiency

The thickness of carbon foil minimum is required to be more than 10μg/cm².

Energy Loss

Energy loss is indicated by the Bethe equation.

$$-\frac{dE}{\rho dx} = 0.307\frac{Z}{A_0\beta^2}\{\log\frac{2mv^2}{I} - \log(1-\beta^2) - \beta^2\} \qquad [MeV/(g/cm^2)]$$

E :Energy Loss
N : The number of carbon atoms per unit volume
A_0 :mass number of carbon
Z :atomic number

β = v / c
v :velocity of injection particle
I = excitation potential=75.1(eV)
m :stationary mass of electron

When injection energy is 11MeV,

Thickness of carbon foil	Energy Loss [eV]
10μg/cm²	380eV
20μg/cm²	760eV
30μg/cm²	1140eV

As thickness of the carbon foil becomes thin, energy loss decreases.

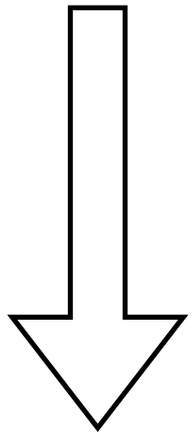
It is available to supply 2keV with a high-frequency acceleration hole in Main Ring.

If energy loss is large, the beam can not be accelerated.

The thickness of carbon foil maximum is required to be less than 20μg/cm² .

Determine the thickness of carbon foil

- From the view of point charge-exchange efficiency, thickness of the foil is required to be more than 10μg/cm^2.
- From the view of point Energy Loss, thickness of the foil is required to be less than 20μg/cm^2.



The thickness of carbon foil is determined to be 10μg/cm^2～20μg/cm^2

The thickness of carbon foil and it's temperature rises

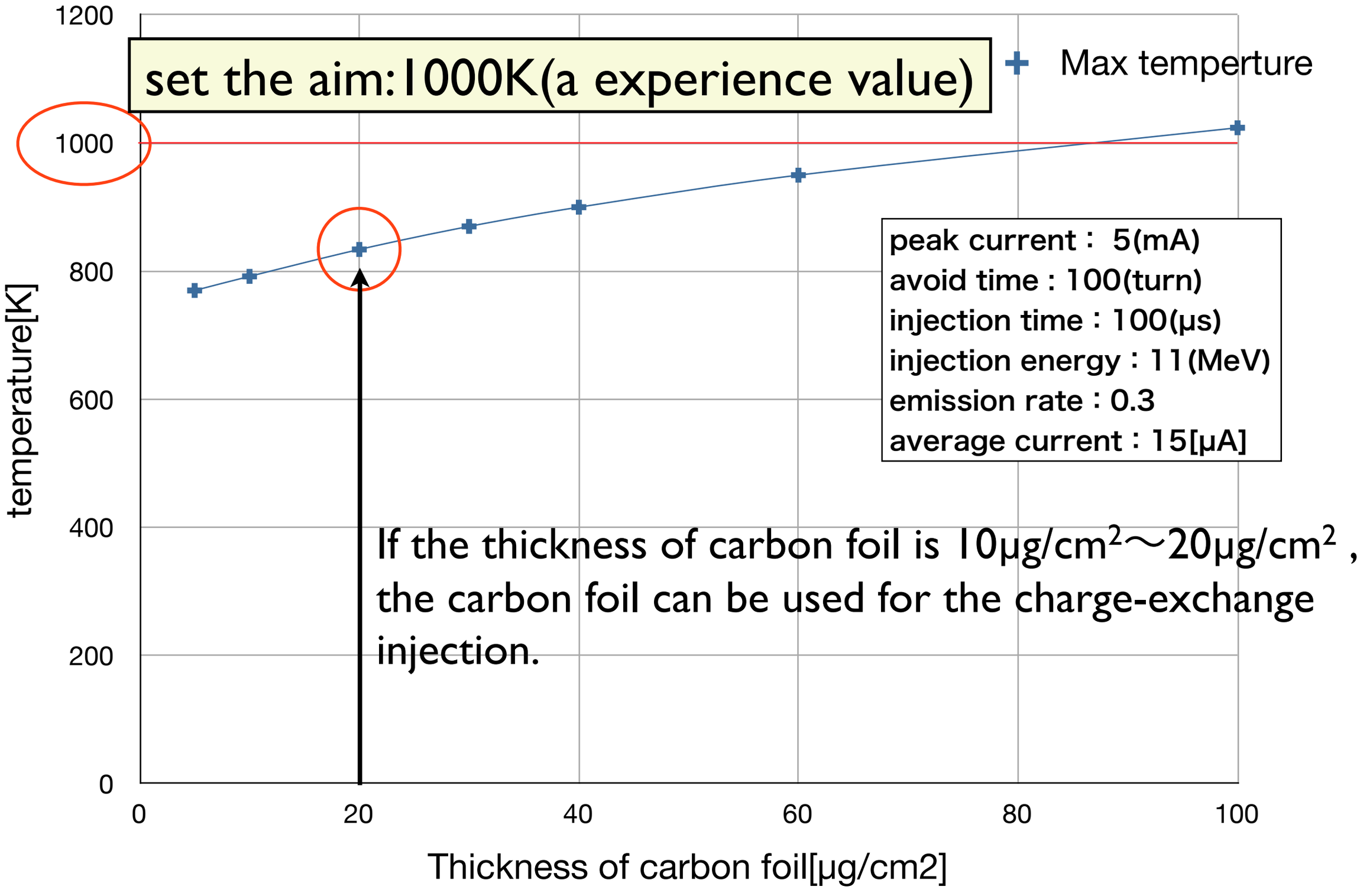


Figure 2 Relation of temperature to thickness of carbon foil

Structure of the charge-exchange carbon foil

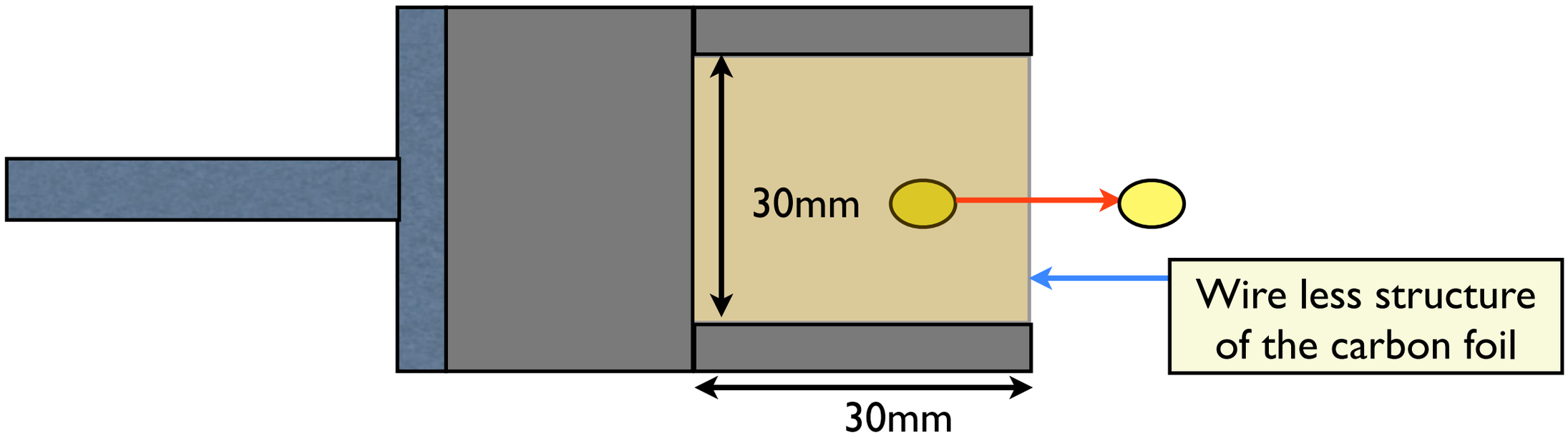


Figure 3 Structure of charge-exchange carbon foil

- The frame is Aluminum.
- Thickness of the carbon foil is 10μg/cm^2～20μg/cm^2 .
- As the beam is accelerate,the beam move outside carbon foil.

The fabrication method of the carbon foil

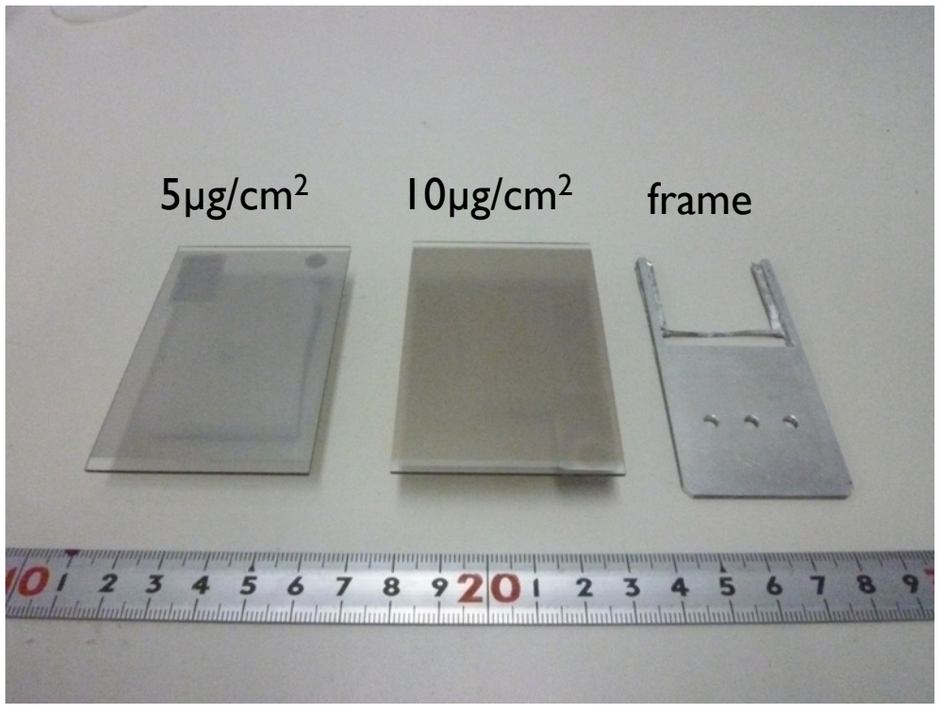


Figure 4 the Photo of the carbon foil and frame
Ligth(5μg/cm^2) Middle(10μg/cm^2) Rigth(frame)

The thin wire is set on the frame to hang the carbon foil.

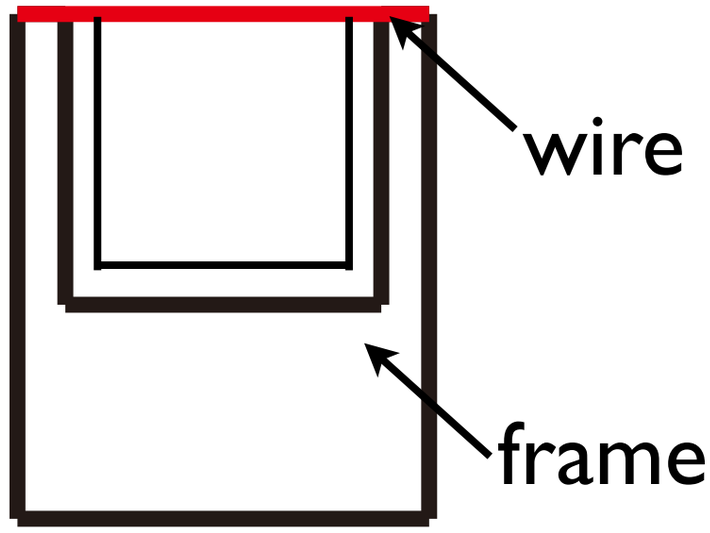


Figure 5 structure of the frame

- The thin wire is set on the frame like a red line in figure.
- Thickness of the carbon foil becomes doubly include by hanging it on the wire.
- Thickness 10μg/cm^2 and 20μg/cm^2 of carbon foil is completed.

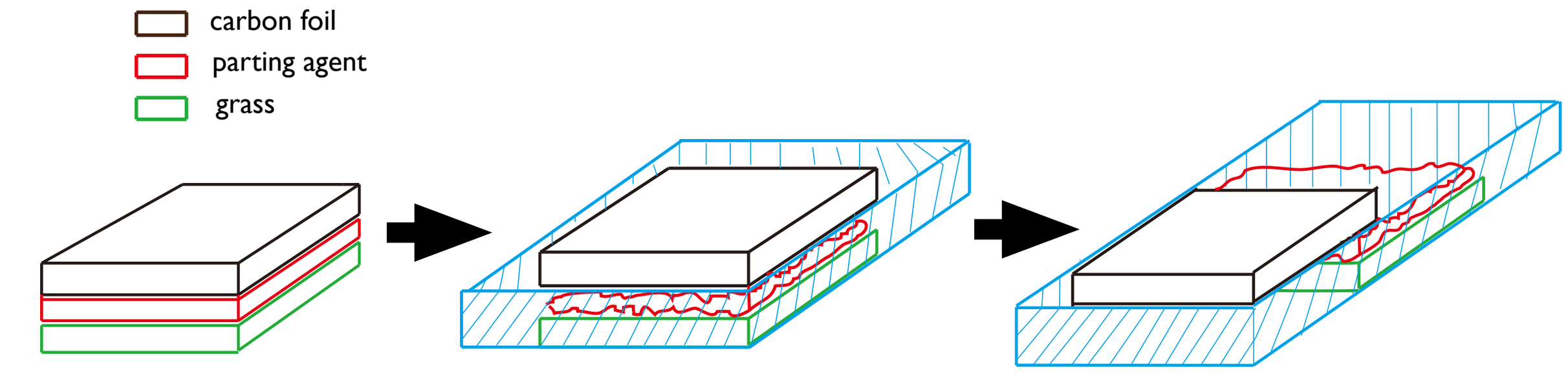
Way to pull out carbon foil

＜It is important to pull out carbon foil with clung parting agent＞

Thickness 5μg/cm^2 and 10μg/cm^2 of carbon foil is very thin and fragile.

⇨ To pull out the carbon foil , it use a surface tension of the water.

The procedure to pull out carbon foil on the grass

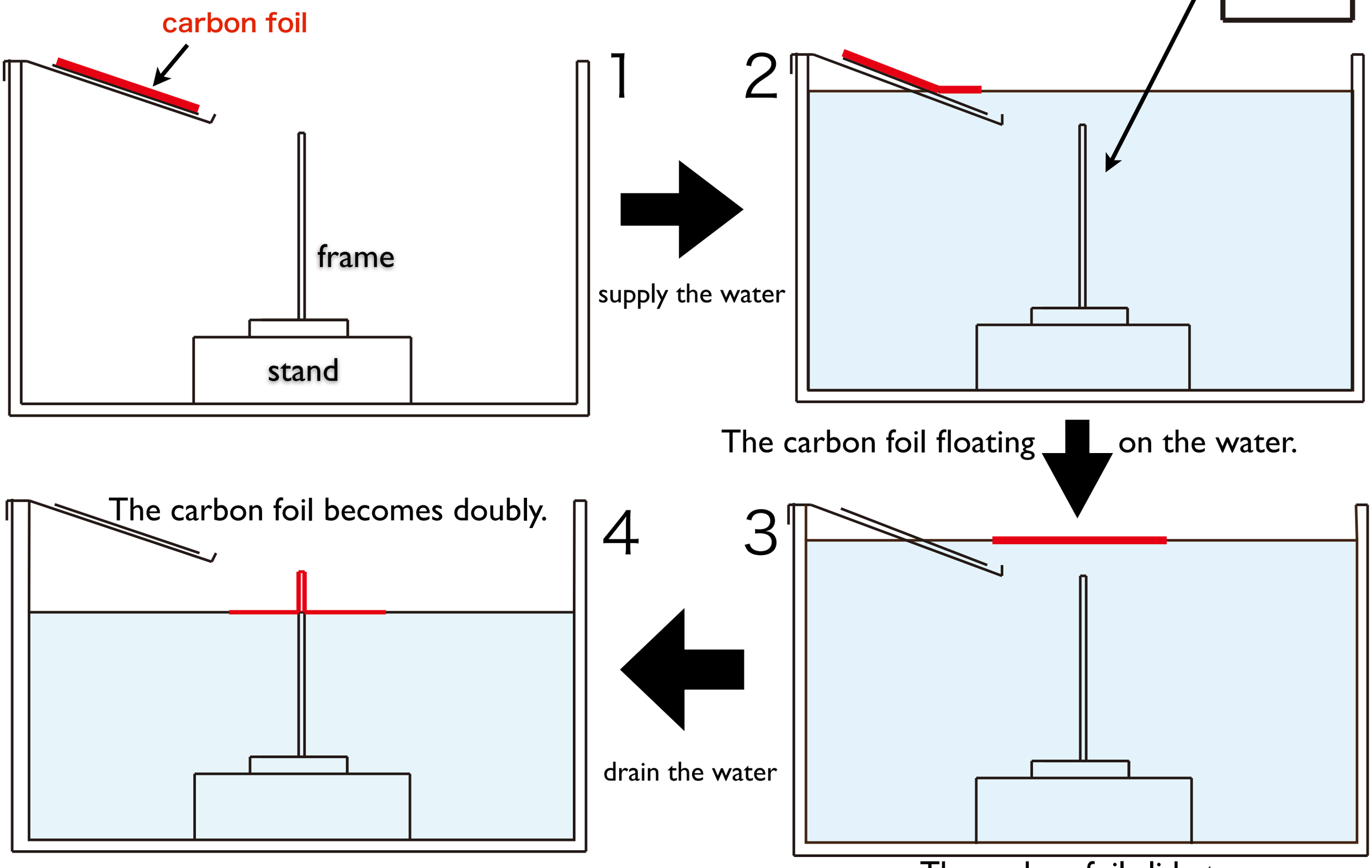


Carbon foil to the water slowly.

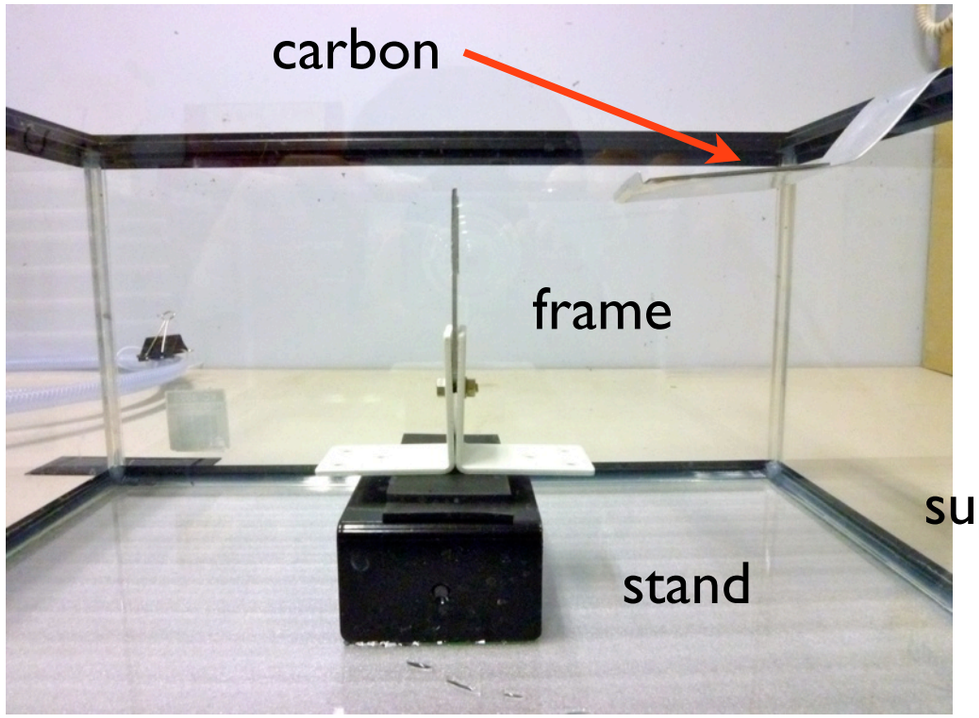
Parting agent dissolve the water.

Carbon foil floating on the water.

The procedure to fabricate the carbon foil



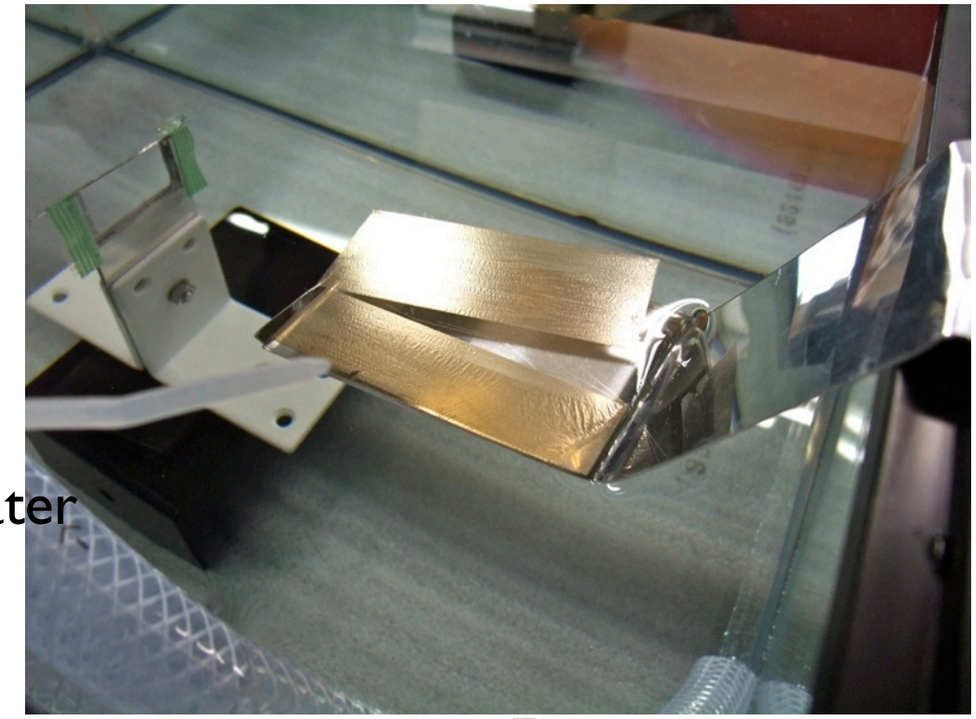
Outline of fabrication of the carbon foil



1

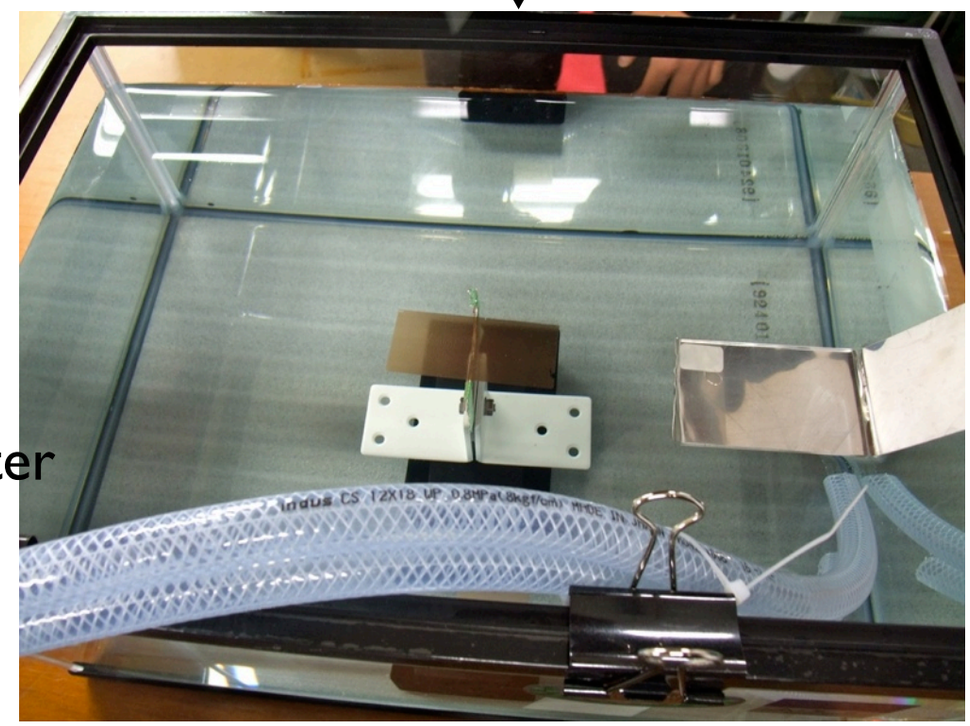
supply the water

2



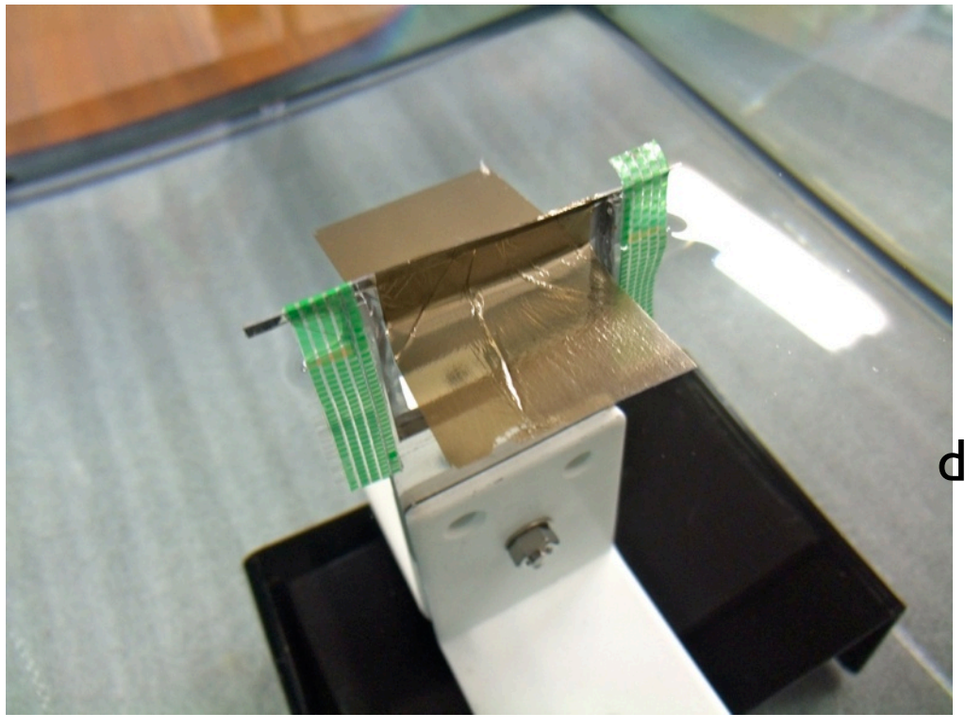
Carbon foil slide to center of frame.

3



drain the water

4



The carbon foil after pulling out from the water

Dry to 30 minutes ⇨ Anneal ⇨ To remove the wire, the carbon foil is cut with a cuter like the red line.

Way to anneal

Carbon foil is heated by halogen lamp. —then→ Carbon foil's tolerance is improved.

The reason is

In the procese of the beam shift from the carbon foil, Beam hit the wire and the beam should be lost.

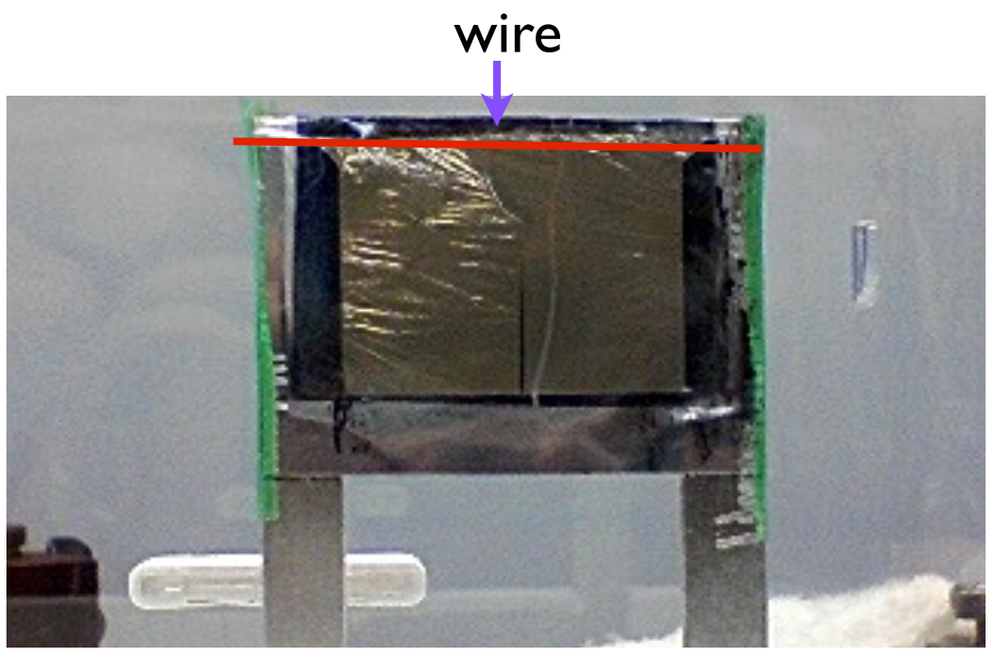
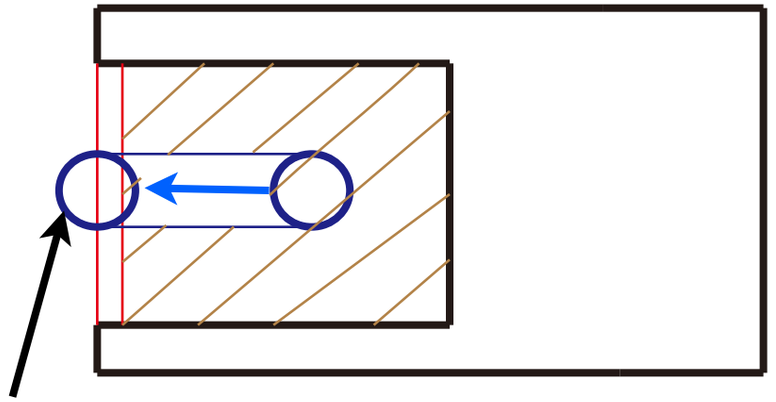


Figure 6 thickness 20μg/cm^2 of the carbon foil



The beam collides a wire.

New fabrication of the carbon foil

- The new frame is fabricated like a figure 7.
- Pulling out of the carbon foil and get it through the red hole.
- Sliding the carbon foil in the center of the new frame and draining the water.

Get the carbon foil through the hole.

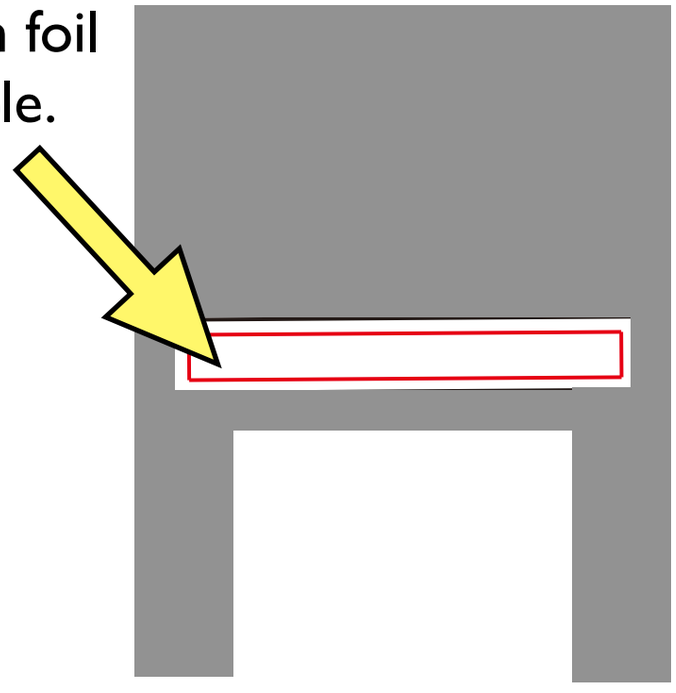


Figure 7 the new frame

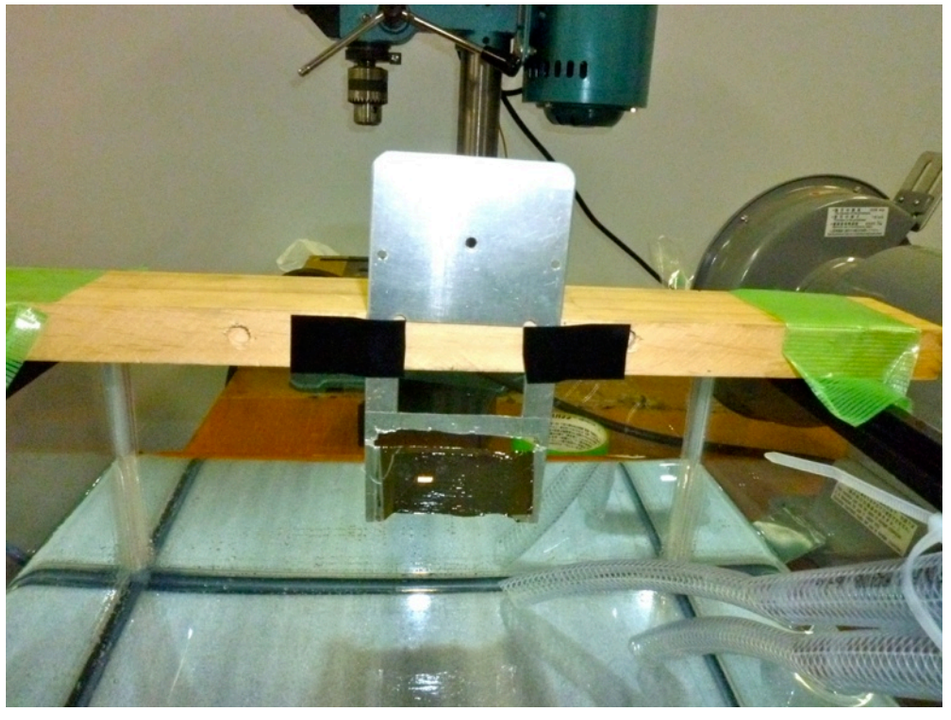


Figure 8 the photo of the new frame

We have succeed to fabricate wire less carbon foil

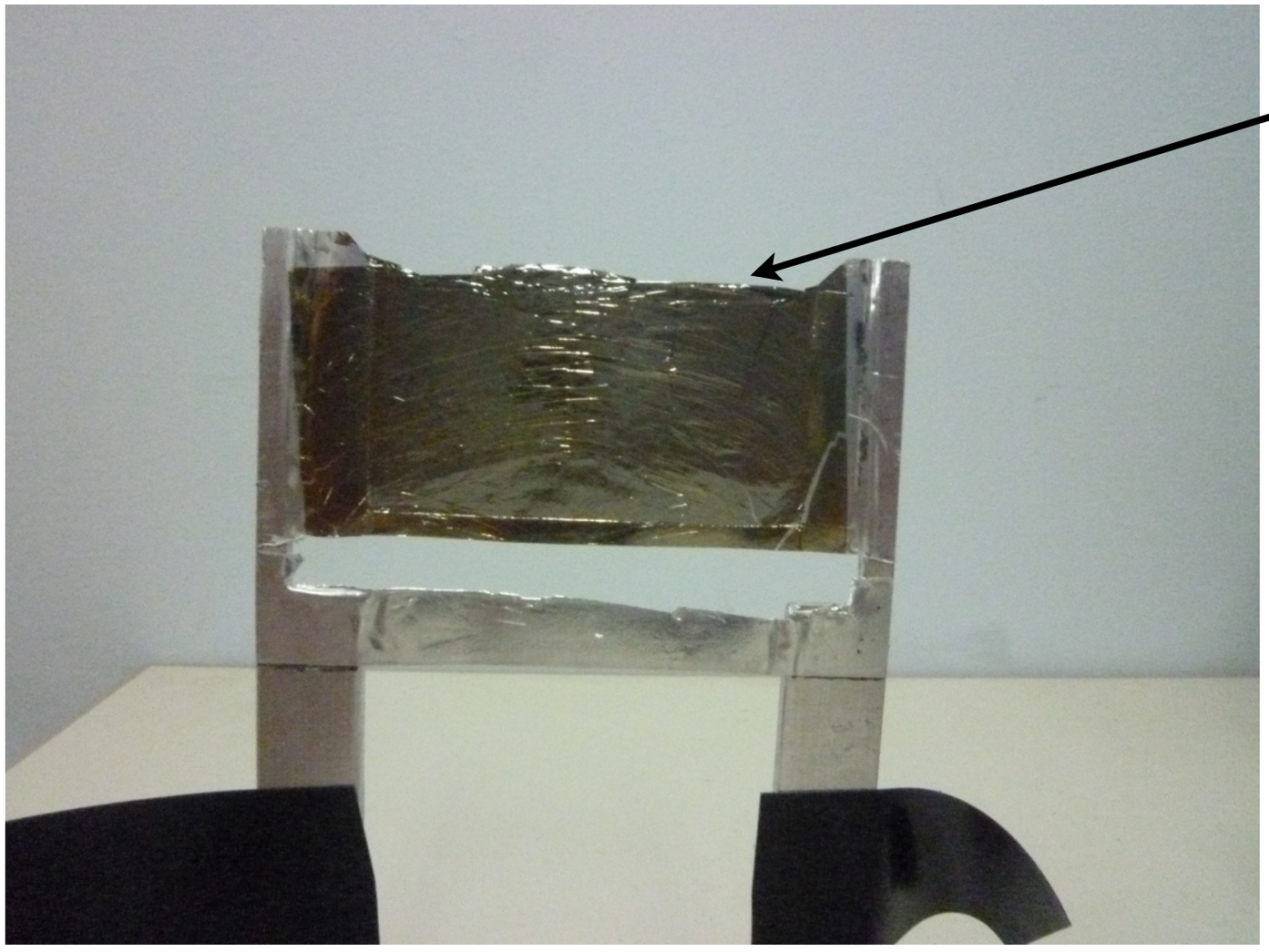


Figure 8 thickness 20μg/cm^2 of the carbon foil

Summary

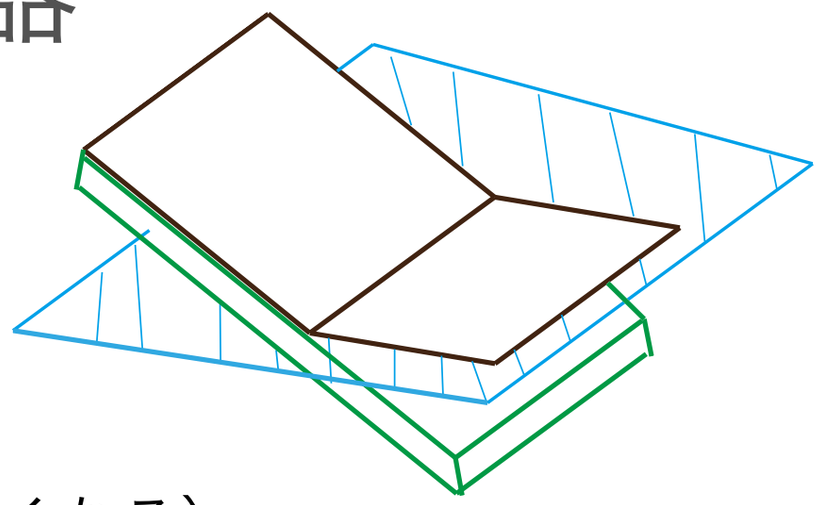
- Suitable thickness of carbon foil is 10μg/cm^2 ～ 20μg/cm^2 which is decided by charge-exchange efficiency and energy loss.

- We have succeed to fabricate the carbon foils of which thickness are 10μg/cm^2 ～20μg/cm^2.

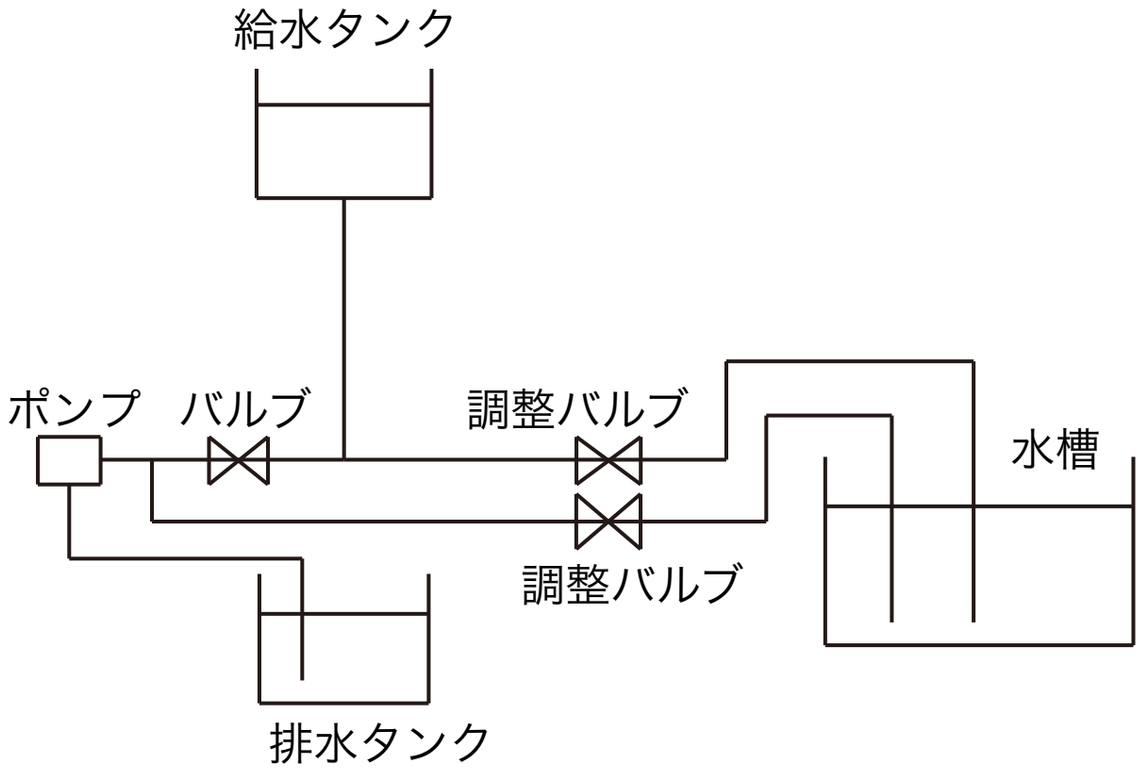
Thank you for your attention

フォイル製作用機器

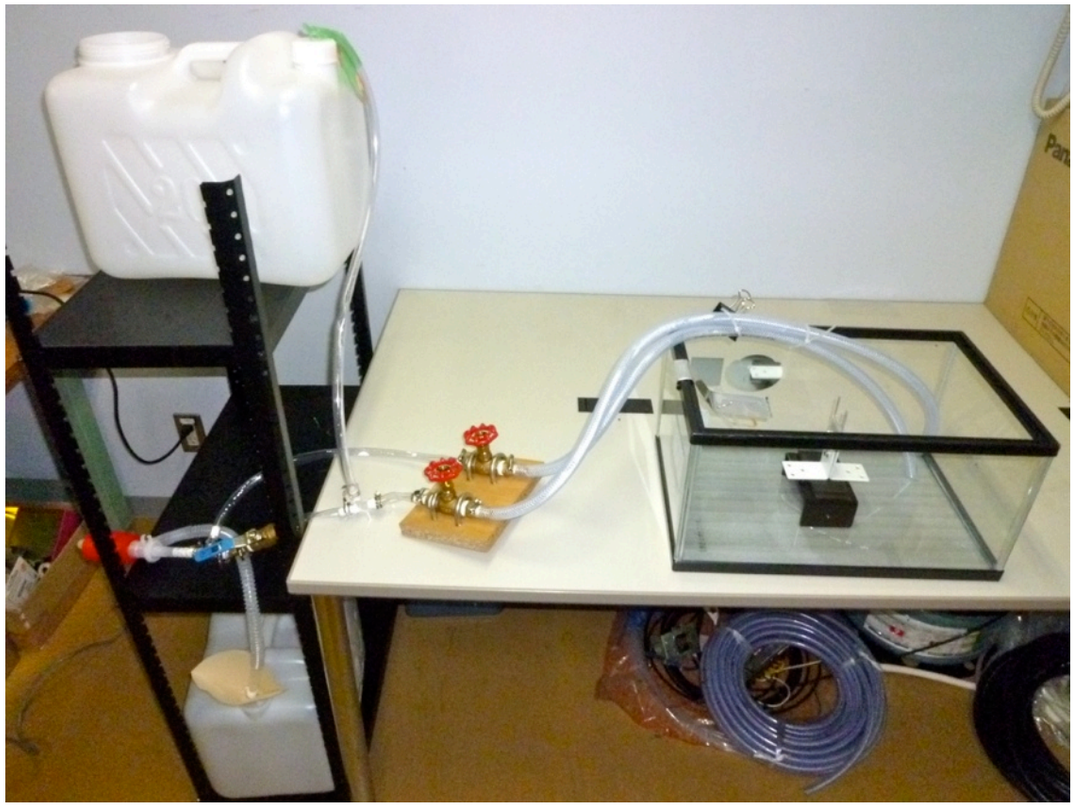
・排水はサイホン方式を採用する
（ポンプは水面を揺らさないようにするため使用せず）
・水に少量の界面活性剤を入れる。
（水の表面張力を弱くするため:カーボンフォイルがはがれ易くなる）
・フォイルを剥離する時、均一な水面移動が重要である。



理想的な水面移動



フォイル製作用機器の概念図



フォイル製作用機器の写真