



ICIB - Superconductive Detectors Group



Annular Superconducting tunnel Junction with injected current as a new configuration of radiation detector



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Overview



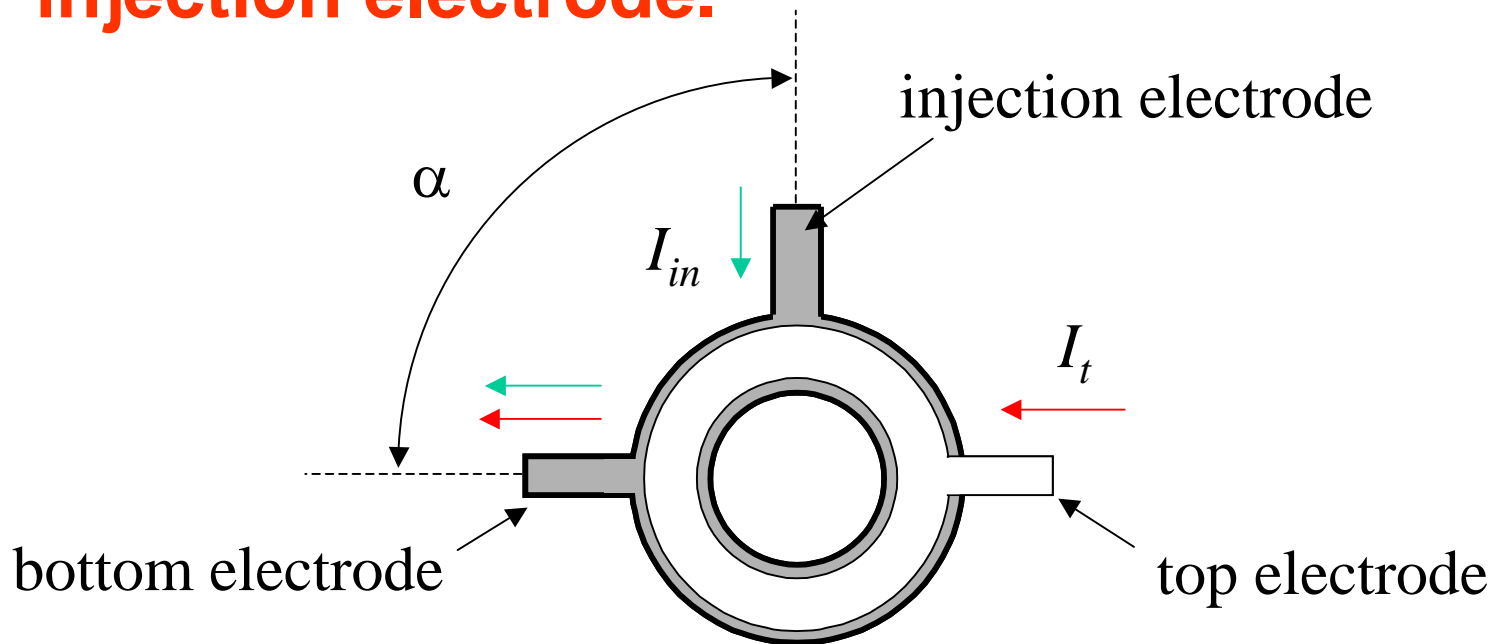
1. Introduction: motivations of the present activity
2. Annular Josephson tunnel junction with injection electrode
 - trapping of magnetic flux quanta
 - injection current application
3. Experiment
4. Conclusions



Why do we think about removing of the external magnetic field from the STJ detector operation?

1. The need for an external magnetic field , and hence, a magnetic coil, complicates the STJ detector application when space for detector installation is limited.
2. The problem to find a field value which simultaneously suppresses the Josephson critical current of several STJs connected in array.

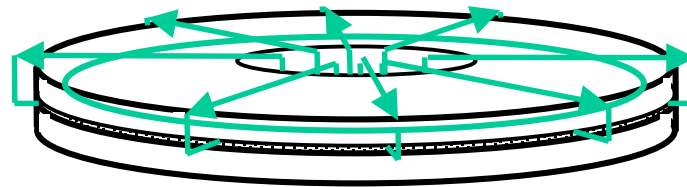
Annular superconducting tunnel junction with injection electrode.



I_t is the tunnel current

I_{in} is the injection current which flows only through the bottom electrode.

Trapping of magnetic flux quanta inside one of the electrode of an annular junction.



Magnetic flux inside the hole is

$$\Phi = SH = n\Phi_0$$

where S is the hole area, H is the magnetic field, $n=0,1,2,\dots$,

$\Phi_0 = \frac{hc}{2e}$ is the flux quantum ($2,07 \times 10^{-7} \text{ Gcm}^2$)

Effect of trapped magnetic flux quanta on the Josephson critical current

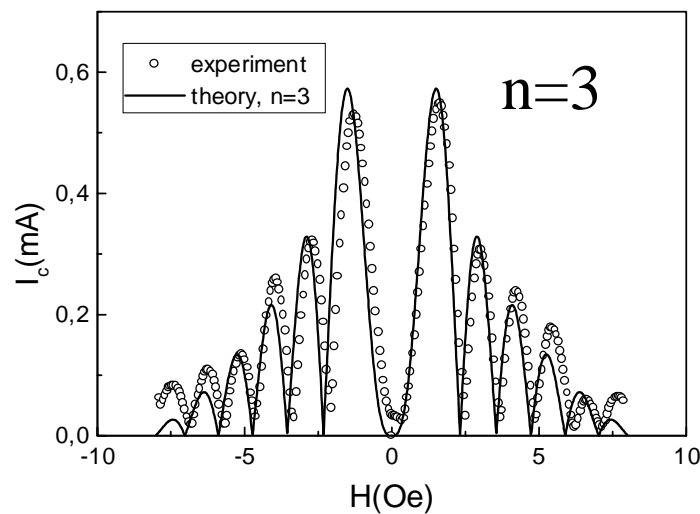


$$I_c = I_0 \left| \frac{2}{(1-\delta^2)} \int_0^1 x J_n \left(x \frac{H}{H_0} \right) dx \right|$$

n is the number of trapped magnetic flux quanta

$$\delta = Ri/Re$$

Main prediction is that, with $n \neq 0$, $I_c(0) = 0$



Nb/Al/Al₂O₃/Al/Nb, $D_{\text{ext}} = 90 \mu\text{m}$, $D_{\text{int}} = 60 \mu\text{m}$

Effect of trapped magnetic flux quanta on the Fiske resonances

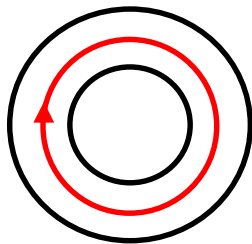
Voltage positions of Fiske steps is defined by

$$V = X_{km} c' \Phi_0 / 2\pi R_e$$

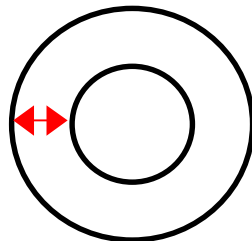
where c' is the Swihart velocity,
 $k=0,1,2,\dots$ (number of trapped flux quanta)

$m=1,2,3,\dots$

$m=1$

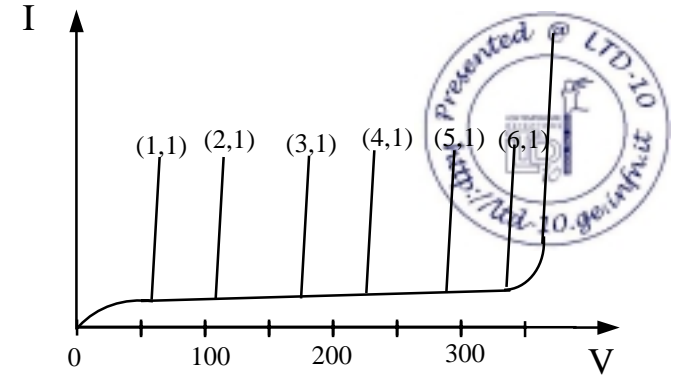


$m=2,3,\dots$

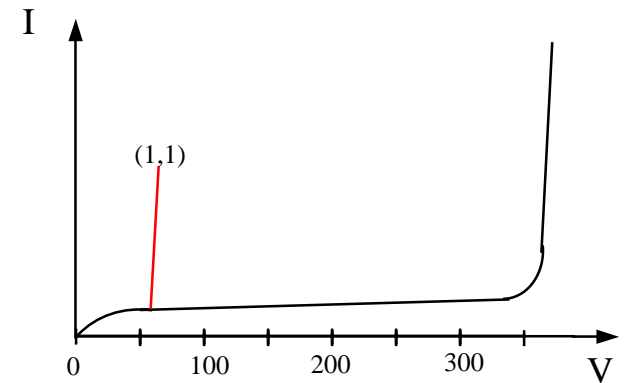


Al/Al₂O₃/Al
 $D_{\text{ext}}=100\mu\text{m}$
 $D_{\text{int}}=60\mu\text{m}$

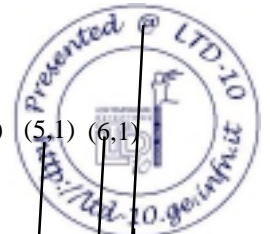
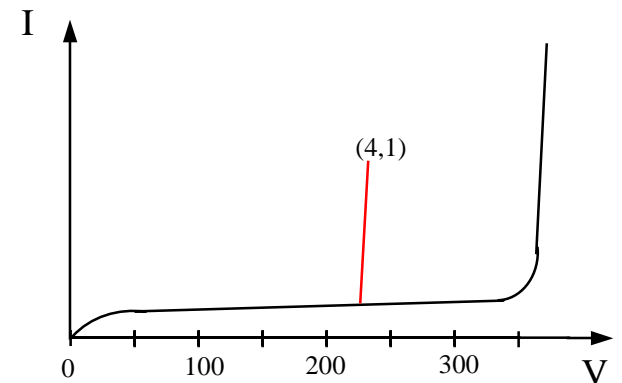
$n=0$



$n=1$



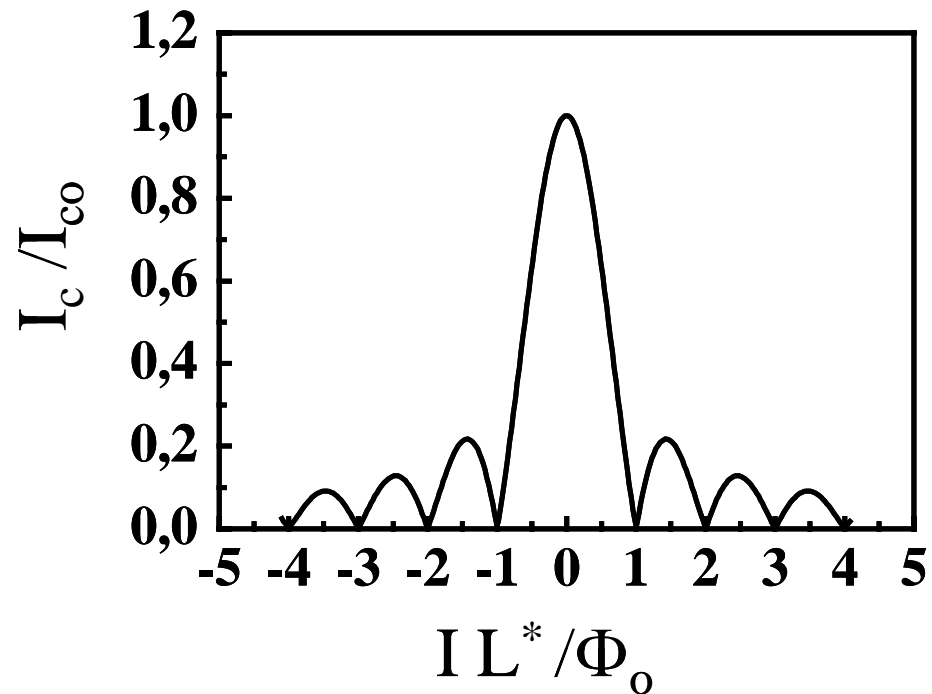
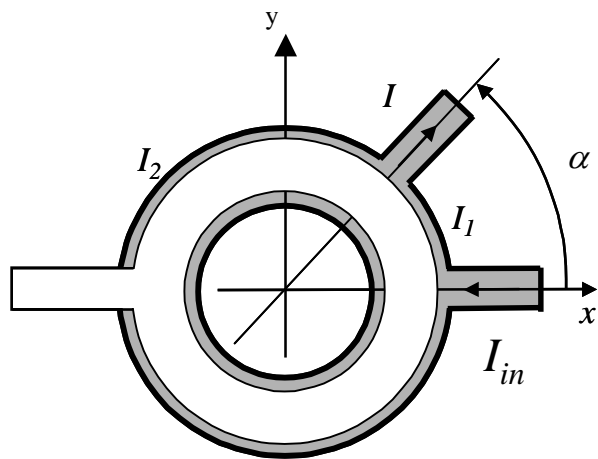
$n=4$



Suppression of the Josephson critical current by injection current in three terminal “Small” annular Josephson junctions

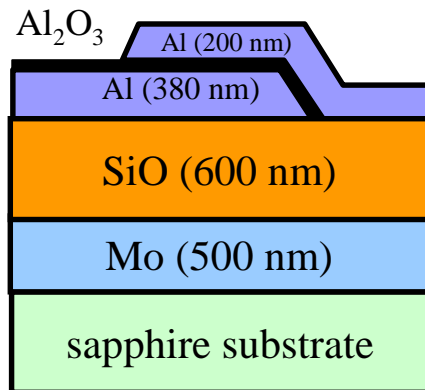


Josephson critical current is modulated by the injection current



$$I_c(I_{in}) = I^{\max} \left| \frac{\sin \pi \frac{I_{in} L^*}{\Phi_0}}{\pi \frac{I_{in} L^*}{\Phi_0}} \right|$$

Al STJ three terminal configuration



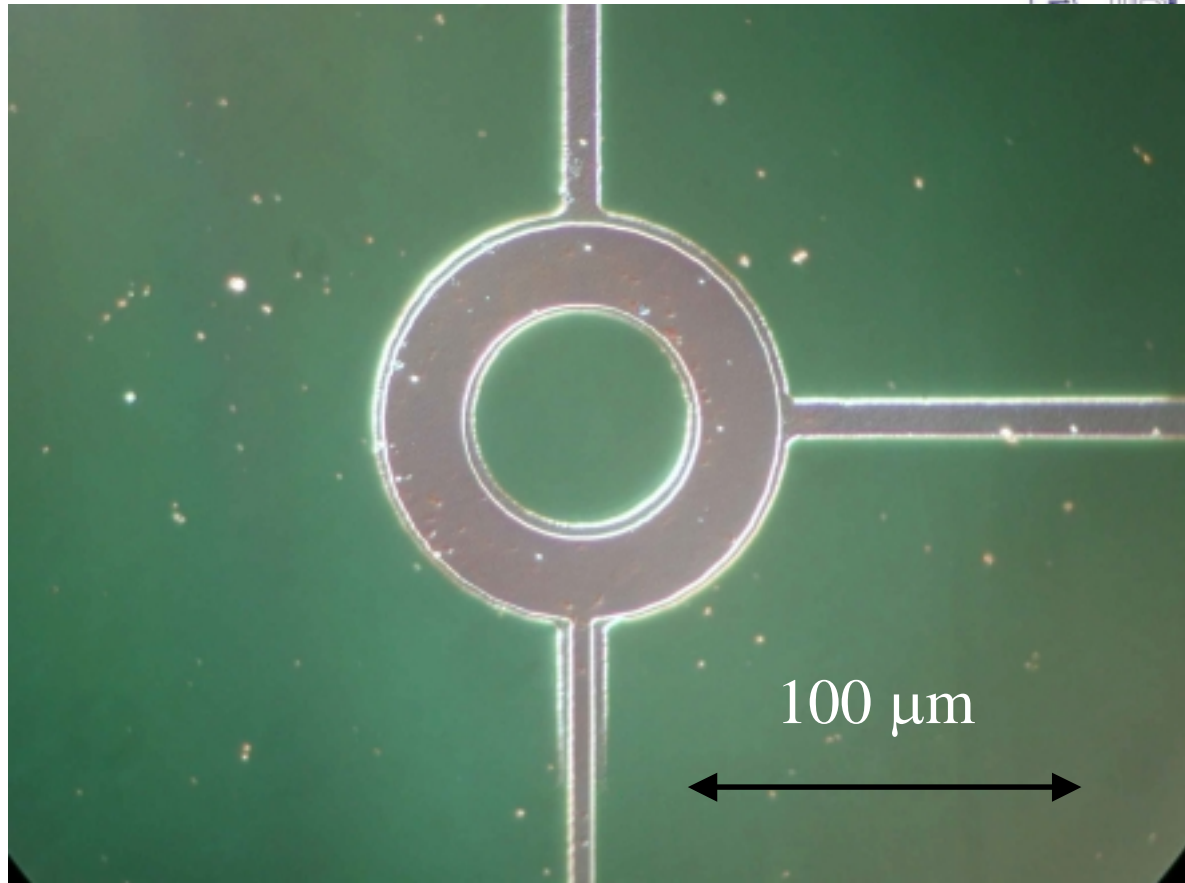
$$D_{\text{ext}}=100 \mu\text{m}$$

$$D_{\text{int}}=60 \mu\text{m}$$

$$\alpha=90^\circ$$

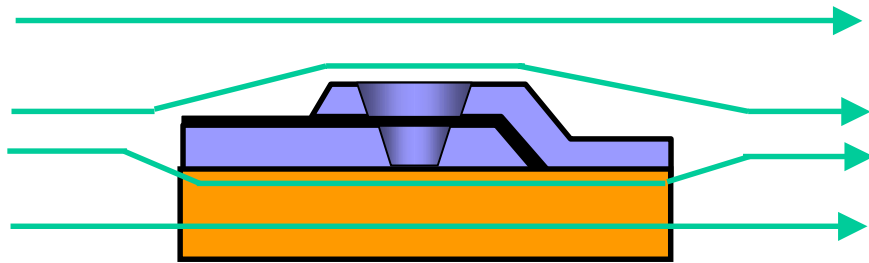
$$j_c=8 \text{ A/cm}^2$$

$$I_q(150 \mu\text{V})=9 \text{ nA}$$

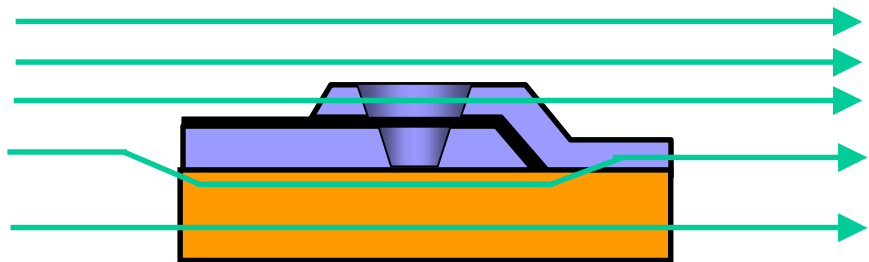


Experimental results under X-ray irradiation from ^{55}Fe X-ray calibration source

Trapping of magnetic flux quanta by applying parallel magnetic field

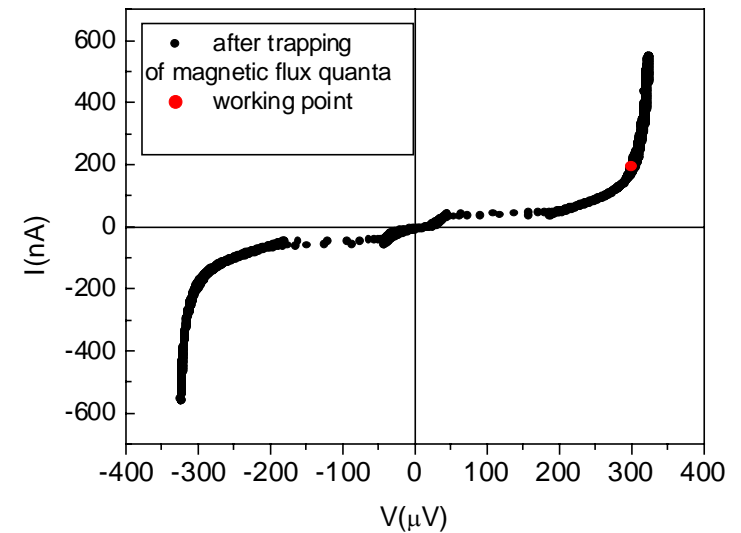
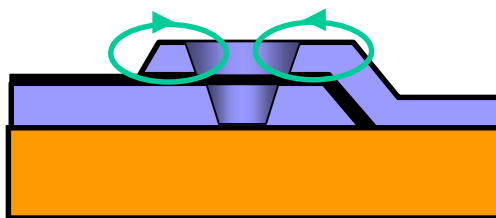


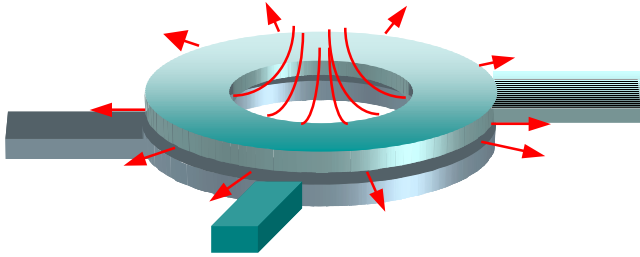
$$H < H_c^{top}$$



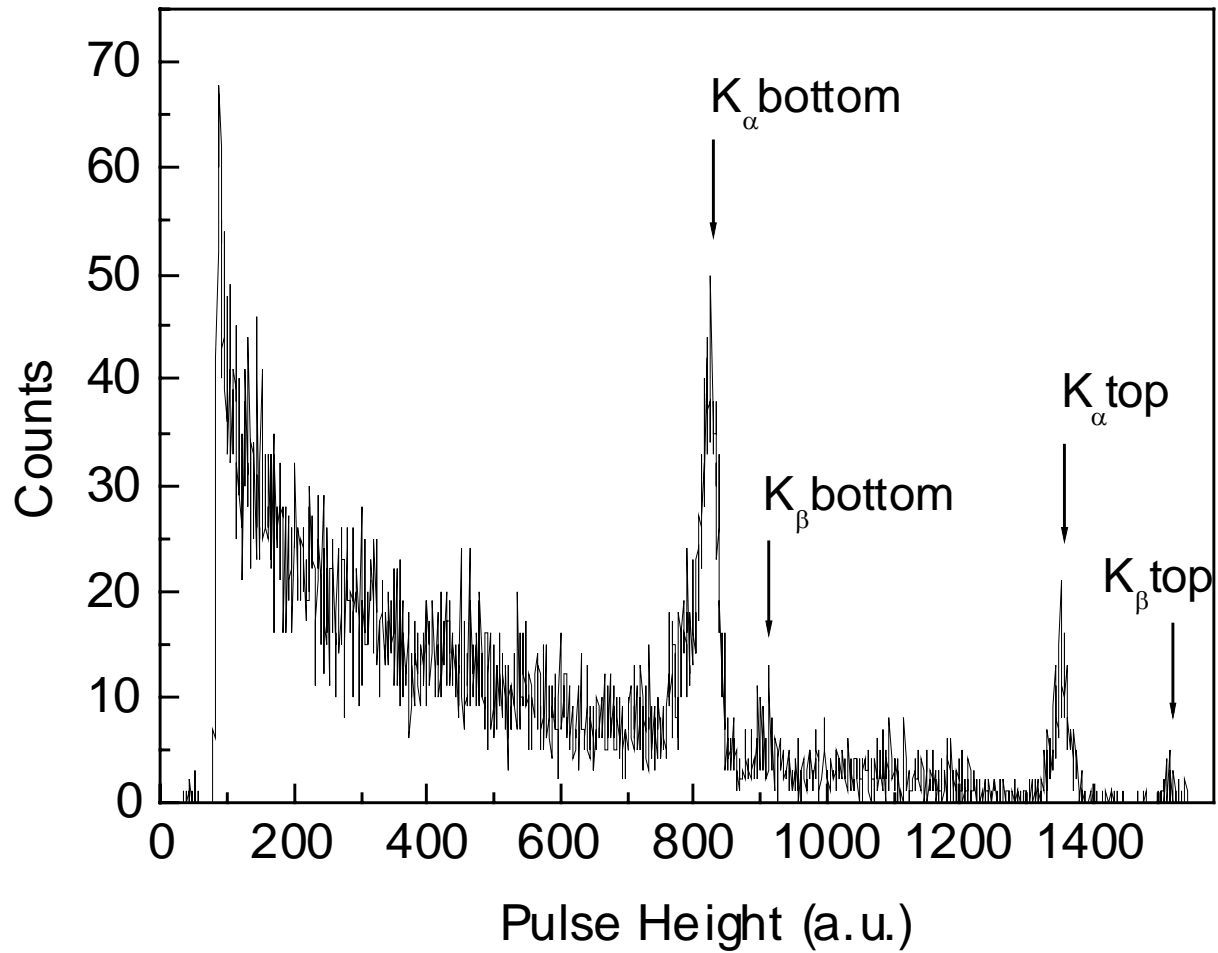
$$H_c^{top} < H < H_c^{bottom}$$

H is turned off

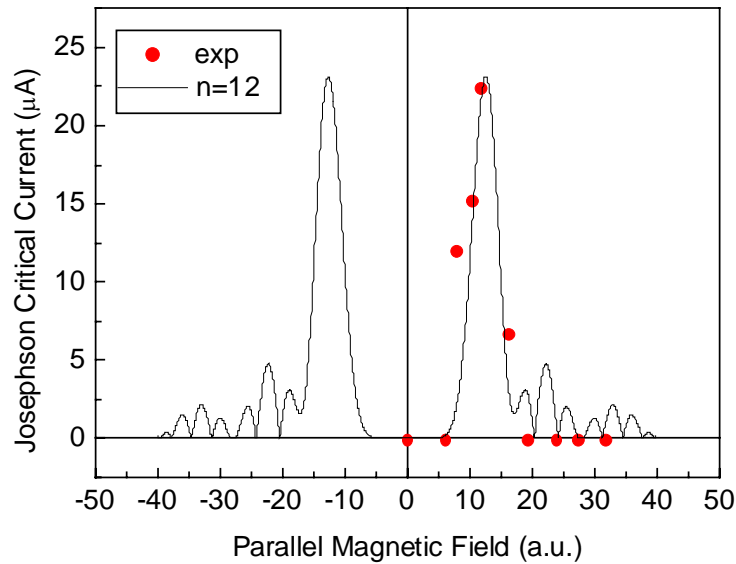
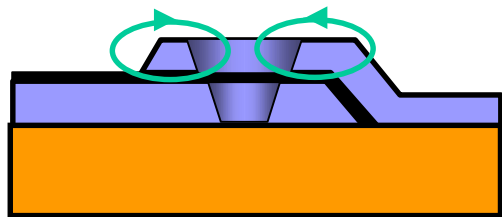




An energy resolution of about 100 eV was obtained for the K_{α} line of the top electrode

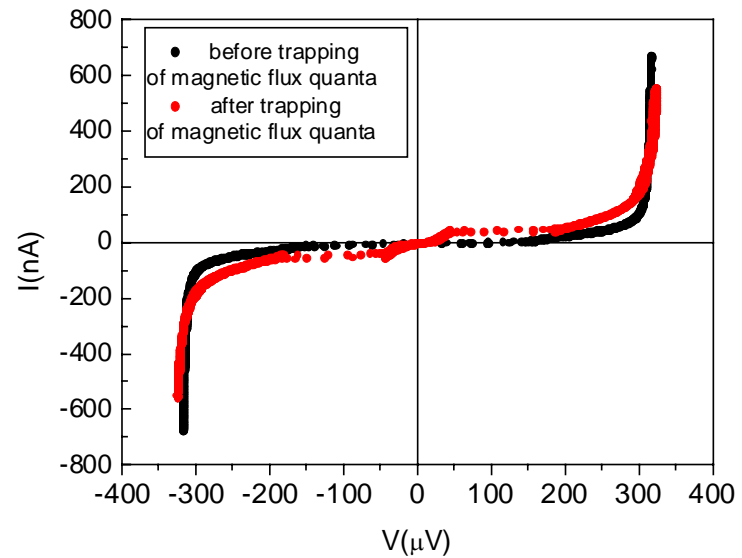
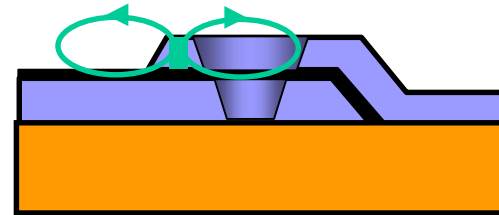


Estimation of the number of trapped magnetic flux quanta



n=12 was obtained

Situation with trapped Abrikosov vortices



The increase of quasiparticle current is due to the presence of **one** Abrikosov vortex

Conclusions

1. High quality annular Al-STJ with injection terminal have been developed.
2. Pulse height spectrum has been obtained for the first time without external magnetic field.
3. The injection current operation appeared to be problematic due to heating of the Al junction wiring. Work is in progress to overcome this problem.



Progress in fabrication of high quality Tantalum film absorber for STJ radiation detector.

J06



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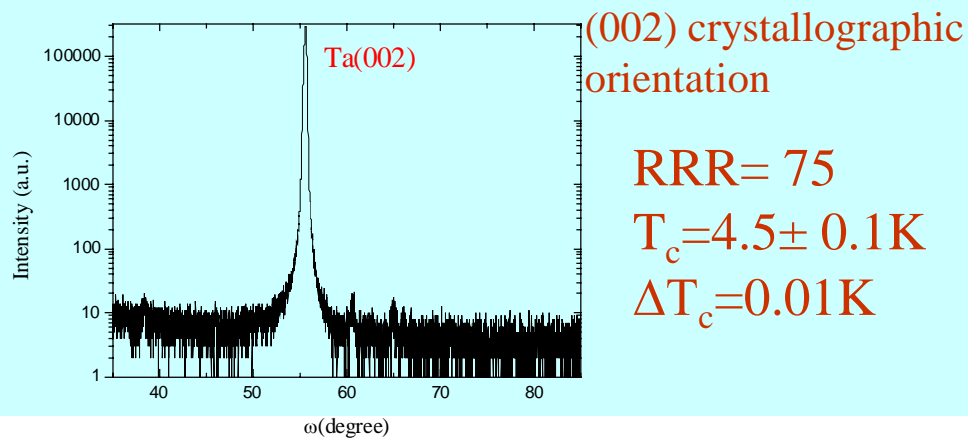
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Deposition methods: magnetically-enhanced dc-triode sputtering

Substrates: R-plane single crystal sapphire at $T=800^\circ$



Ta absorber with lateral Al-STJs

