Experimental Verification of the Occurrence of Rectified Voltage ("Diode Effect") in Multiply Connected Superconducting Structures

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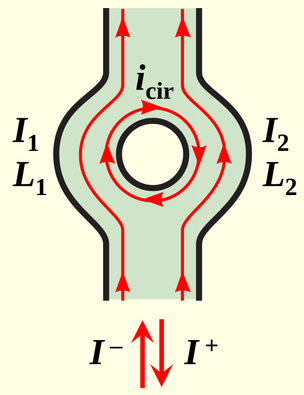
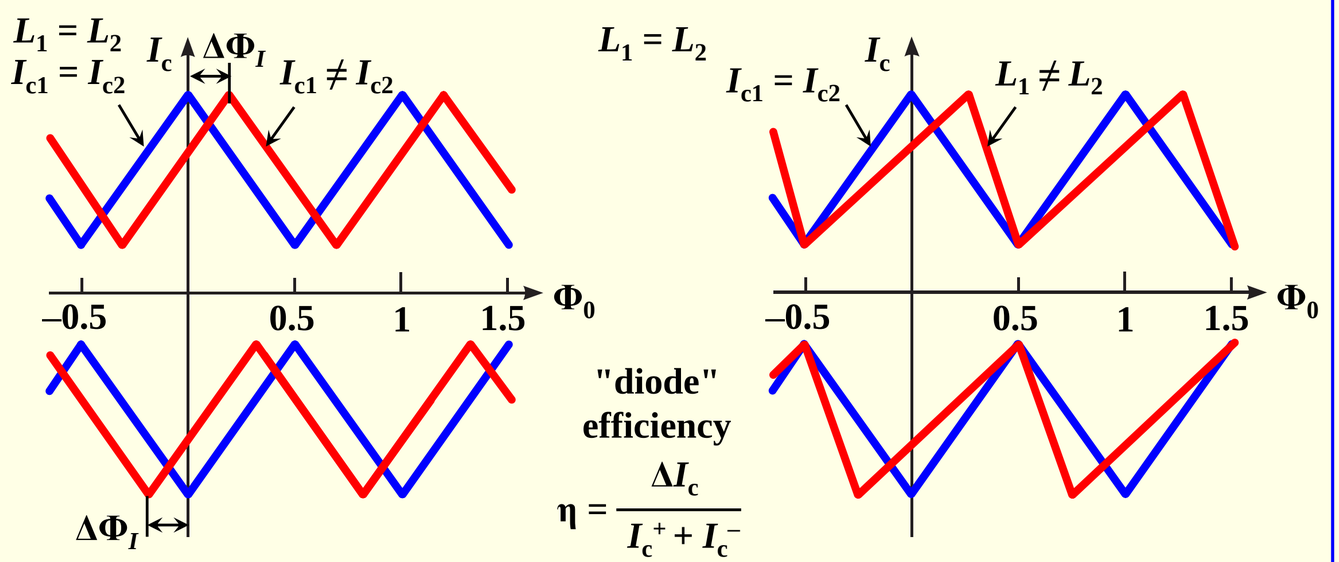
1. Origin of the current rectification effect in doubly connected superconducting film structures

Critical current oscillations in a doubly connected circuit without Josephson junctions as a function of magnetic field arise due to algebraic summation of the circulating and transport currents. Since the circulating current periodically alters its sign when the magnetic field changes, the resistive state appears alternately in that arm of the loop in which the currents are added. If the transport currents in the two arms of the loop are different, an additional magnetic flux arises, which shifts the $I_c(H)$ dependence causing an asymmetry of critical currents, i.e. the diode effect.





"diode" efficiency

$$\eta = \frac{\Delta I_c}{I_c^+ + I_c^-}$$

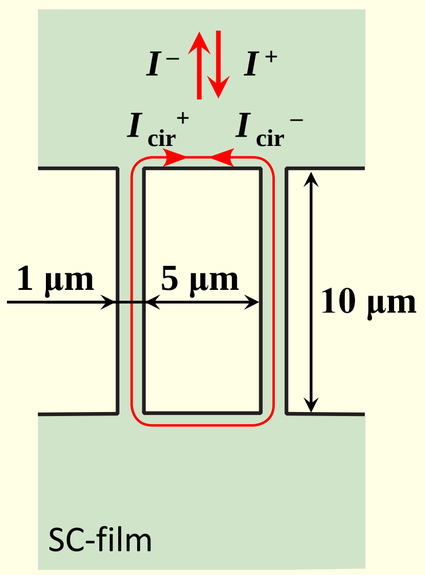
$I_{c1} = I_{c2}$, $\Phi = 0$, $I_c = I_{c1} + I_{c2}$, $\Delta I_c = I_c^+ - I_c^- = 0$

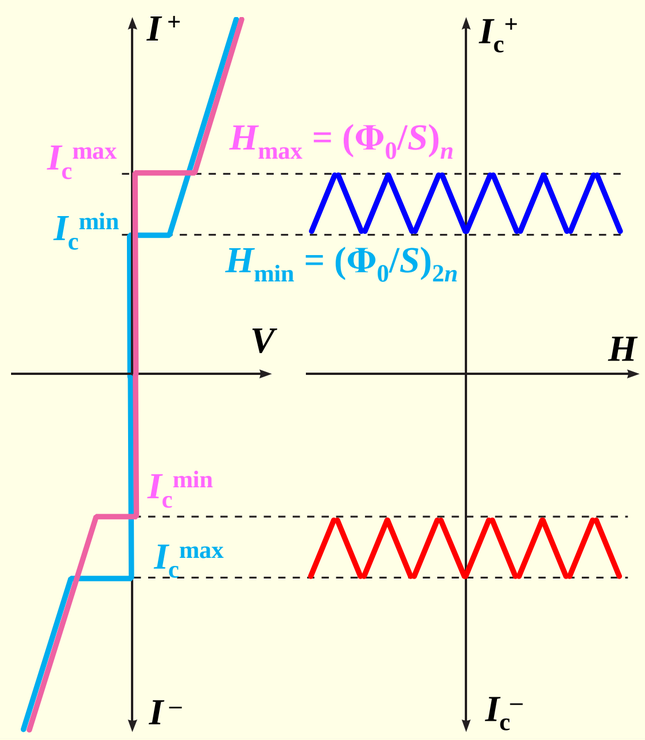
$I_{c1} \neq I_{c2}$, $\Phi \neq 0$, $I_c = I_{c1} + I_{c2}$, $\Delta I_c = I_c^+ - I_c^- = f(H)$

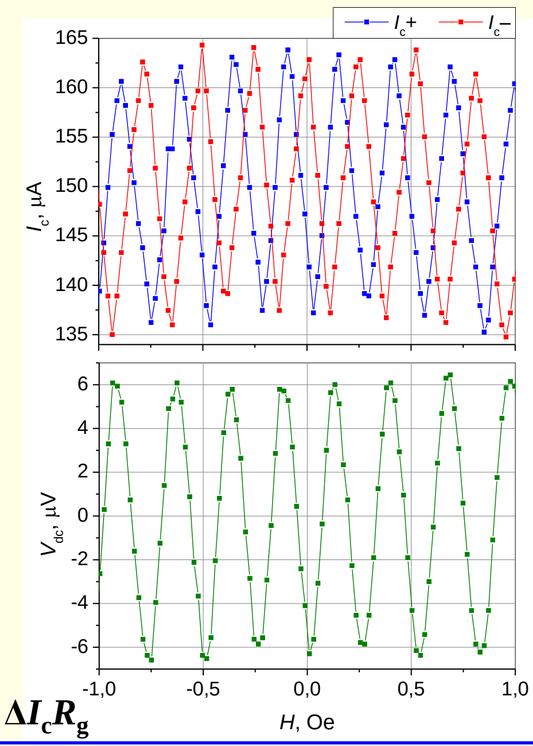
$I_{c1} = I_{c2}$, $L_1 \neq L_2$, $\Delta I_c = I_c^+ - I_c^- = f(H)$

2. Critical current oscillations in a double-connected film circuit with different critical currents in the arms

The critical current oscillation peak-to-peak value is equal to the circulating current, while the maximum difference in critical currents in opposite directions (rectification efficiency) is achieved when the critical currents of the two arms differ by half the circulating current value (π-shift).



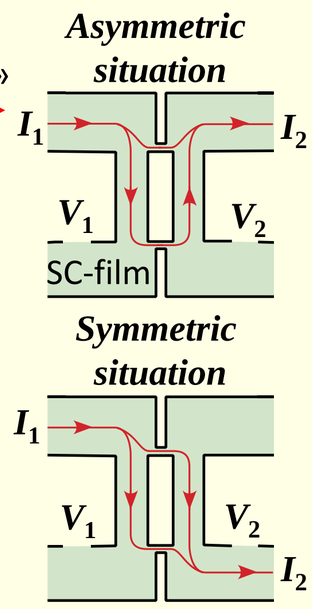


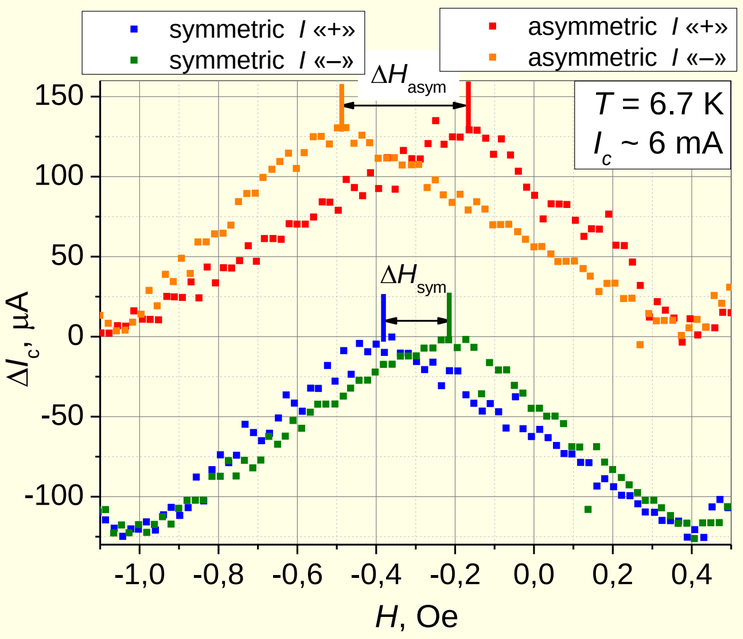


$V \sim \Delta I_c R_g$

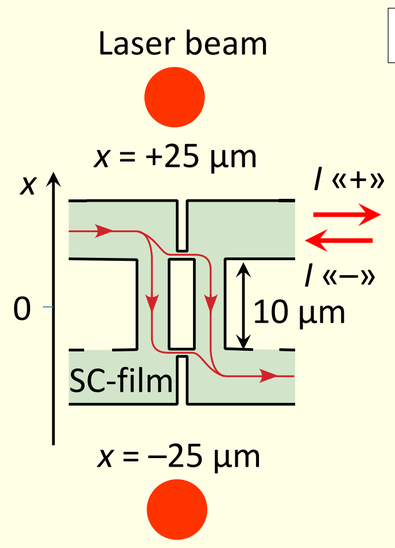
3. Experimentally controlled "superconducting diode" efficiency in doubly connected circuit by changing inductances or critical currents of the loop arms

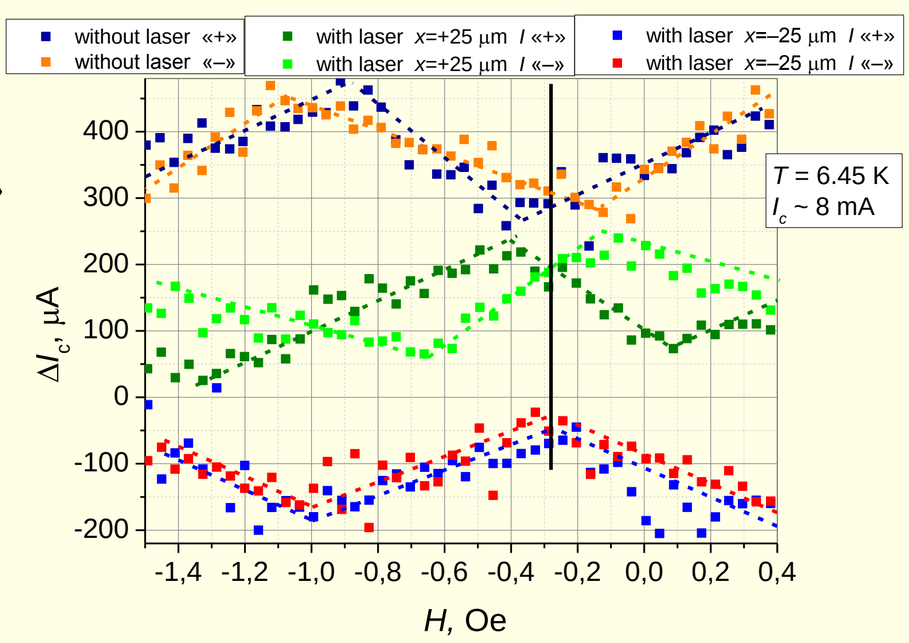
a) inductance-controlled





b) critical-current control using a laser probe





The experimental data are "noisy" because the experiments were made in an unshielded optical cryostat without any filtration, accumulation, etc., and aimed to obtaining only qualitative results.

Conclusion

The critical current of doubly connected superconducting loop without Josephson junctions oscillates as a function of magnetic field due to addition of circulating and transport currents.

It has been experimentally confirmed that this can lead to the appearance of a rectified voltage (diode effect) if the critical currents and/or inductances of the two arms of the loop are different.