Improving detection efficiency of Ti based superconducting transition edge sensors with optical cavity

Y. Geng[1,2,3], W. Zhang[1,2], P.Z. Li[1,2,3], J.Q. Zhong[1,2], Z. Wang[1,2],

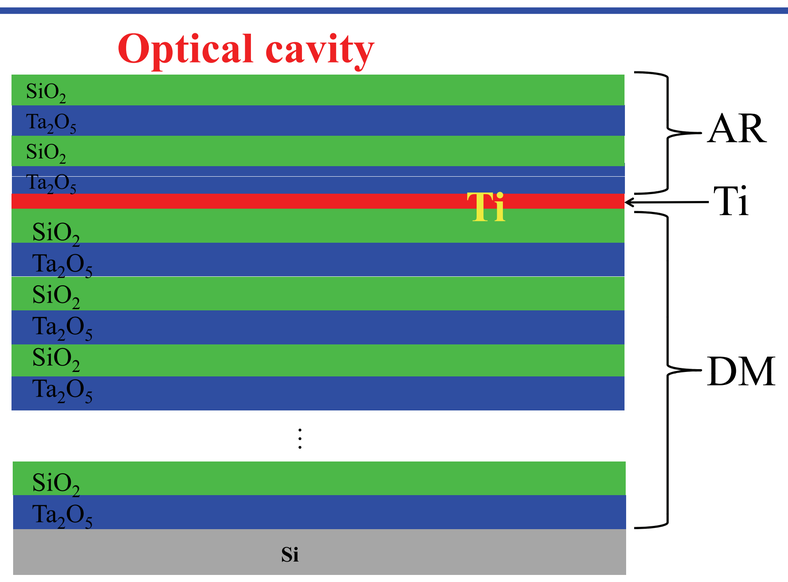
W. Miao[1,2], Y. Ren[1,2], J.F. Wang[4], Q. J. Yao[1,2], S. C. Shi[1,2]

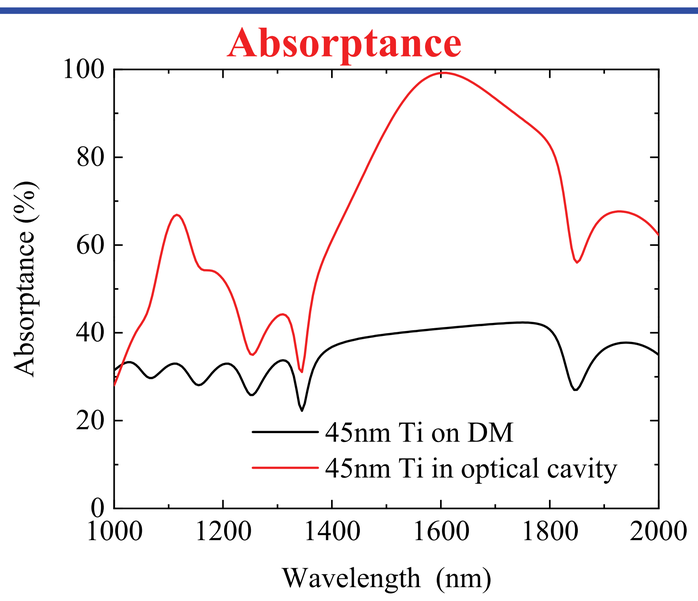
[1]Purple Mountain Observatory, CAS, Nanjing, China
[2]Key Lab of Radio Astronomy, CAS, Nanjing, China
[3]University of Science and Technology of China, Hefei, China.
[4]Nanjing Institute of Astronomical Optics &Technology, CAS, Nanjing, China.

- Superconducting transition edge sensor (TES) single photon detectors have demonstrated high quantum efficiency and photon number resolving capability. *A.E. Lita, et. al., Opt. Express, 16(5), 3032, 2008*
- Furthermore, Ti-based TES is very fast (response time of ~100 ns) thanks to the high critical temperature of ~400 mK. *D. Fukuda, et .al., Proc. SPIE., 7236, &2360C, 2009*
- We have developed Ti-based TES, and studied its electrical and optical performance. *W. Zhang, et. Al., IEEE Trans. Appl. Supercond., 29(5), 2100505, 2019*
- Here, we present the improvement of detection efficiency of Ti-based TES embedded in an optical cavity.

Optical cavity

- Optical cavity composed of anti-reflection coating (AR) and dielectric mirror (DM);
- AR and DM consist of 16 and 4 layers of SiO_2 and Ta_2O_5, respectively;
- Thickness for DM is fixed to 0.25 λ;
- Thickness for AR optimized with Macleod software;
- Absorptance increased by a factor of 2 by adding AR.





Fiber alignment

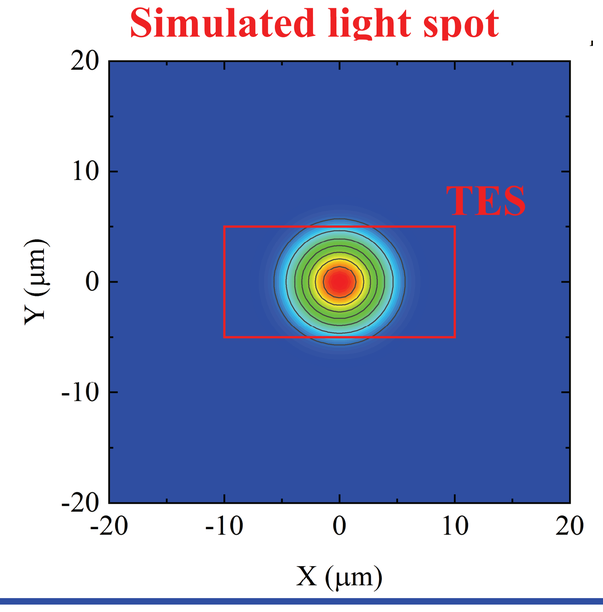
- Fiber ~20 μm far from TES;
- Light spot from the fiber is Gaussian distribution;

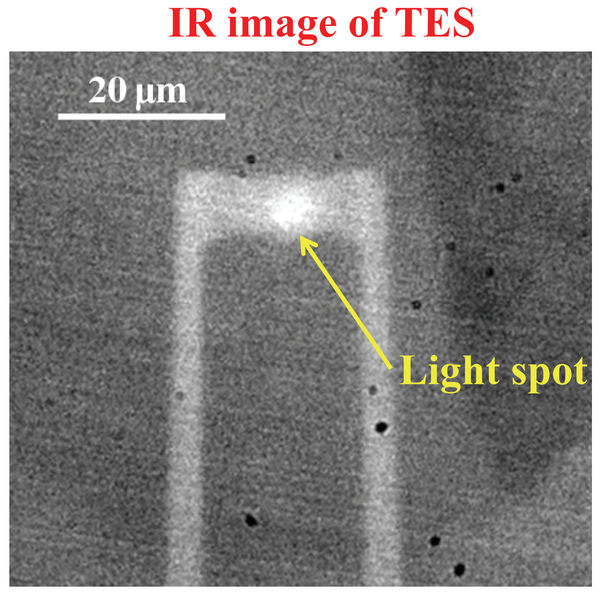
$$I(x,y)=\frac{2}{\pi\omega^2}e^{-\frac{2(x^2+y^2)}{\omega^2}}$$

- TES active area overlaps the light spot;

$$\eta_{coup}=\int_{-a/2}^{a/2}\int_{-b/2}^{b/2}I(x,y)dxdy$$

- Calculated coupling efficiency is over 90%.

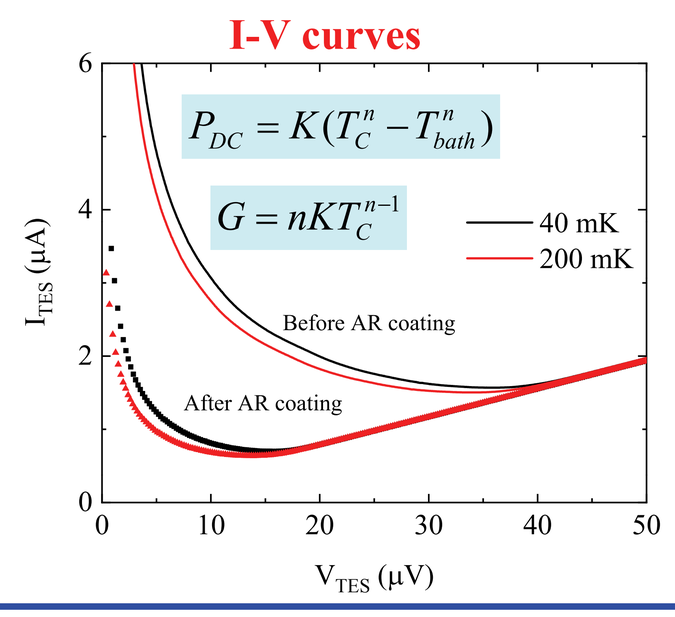


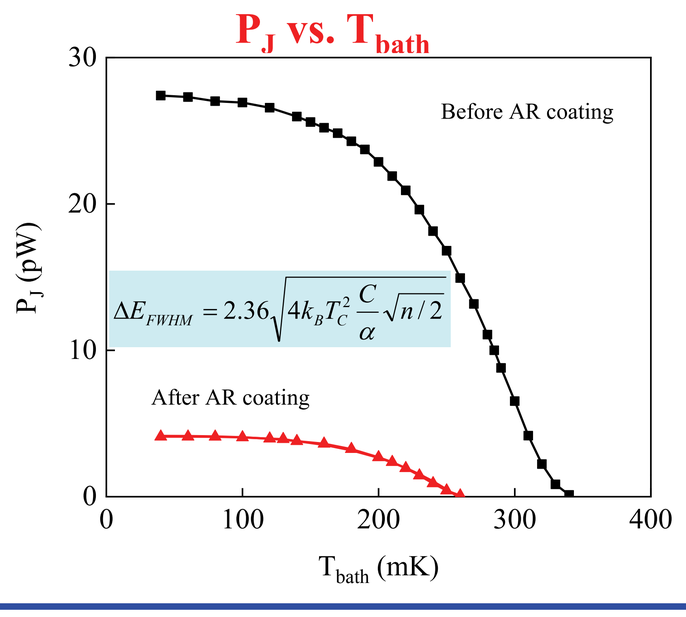


Thermal conductance

- I-V measured with SQUID readout;
- Data points chosen at a resistance of 0.7 Ω;
- G from I-V at different T_{bath}.

	T_C (K)	n	G (pW/K)	ΔE_{FWHM} (eV)	τ_{eff} (μs)
Before AR coating	0.323	3.7	314	0.53	1.7
After AR coating	0.258	4	64	0.35	5.9





Detection efficiency

- Pulse response measured with a 1550 nm laser source;
- Output signal recorded by a digital oscilloscope;
- τ_{eff}=1.7 μs before AR coating, increased to 5.9 μs after AR coating;
- Detection efficiency is 40%, increased by a factor of 2.