ancement of spin-pumping voltage through the spin-Seebeck ef

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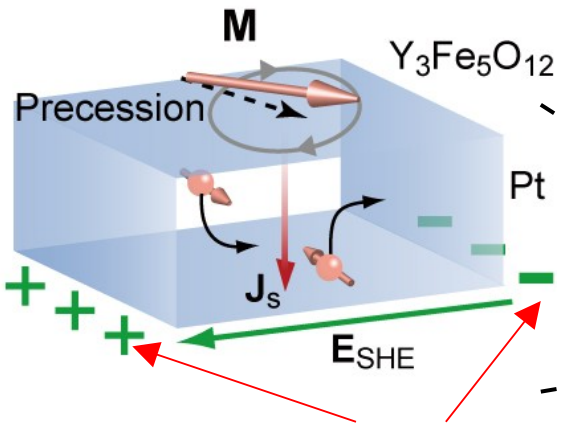
sample set-up

sample system:

$Y_3Fe_5O_{12}$ (2.6 μm) / Pt (15 nm) + heater

spin pumping and inverse spin-Hall effect (ISHE)



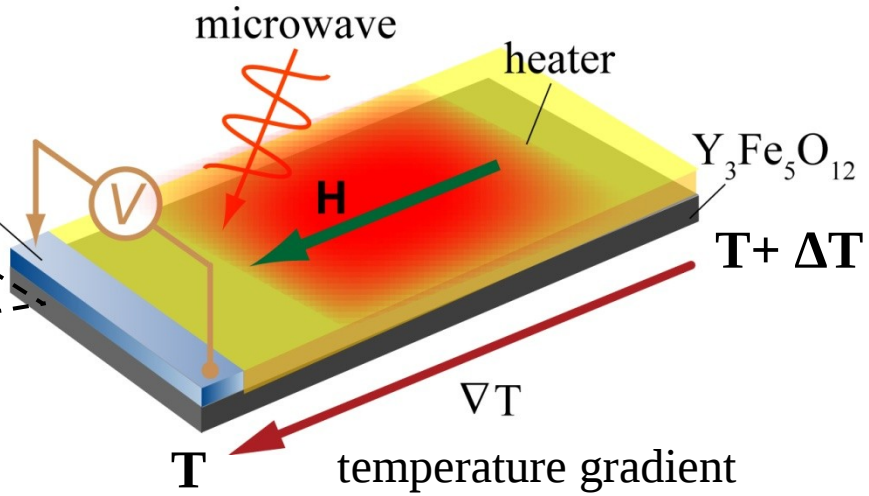
Electromotive force Induced by ISHE

E. Saitoh *et al.*, Appl. Phys. Lett. **88,** 182509 (2006).

$$\mathbf{E}_{SHE} \propto \mathbf{j}_s \times \boldsymbol{\sigma}$$

(Power P = 0 ~ 2.0 mW)

9.44 GHz

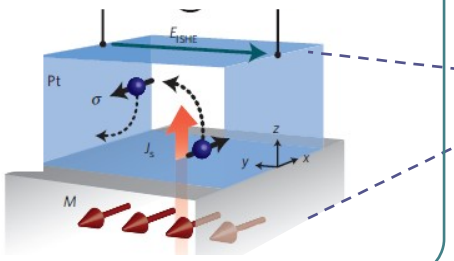


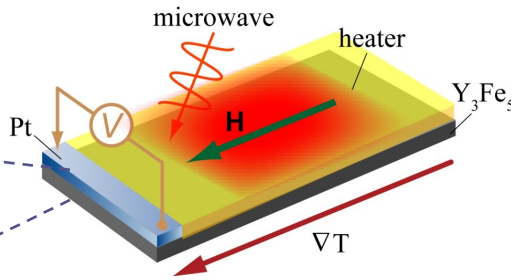
(temperature difference ΔT = 0~18.9 K)

measuring spin-pumping voltage with applying temperature gradient
(spin pumping effect + spin-Seebeck effect)

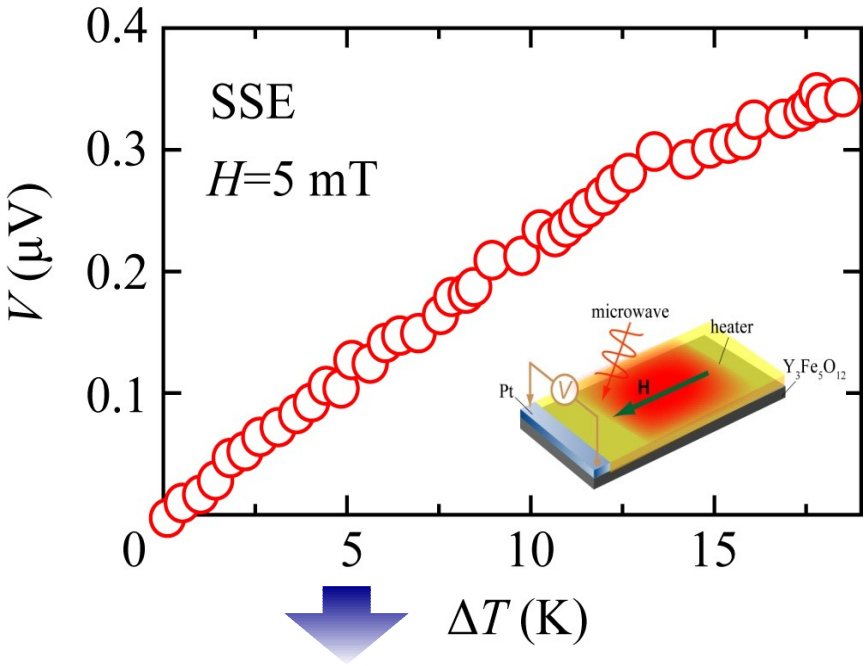
H dependence of *V* (spin-Seebeck effect)

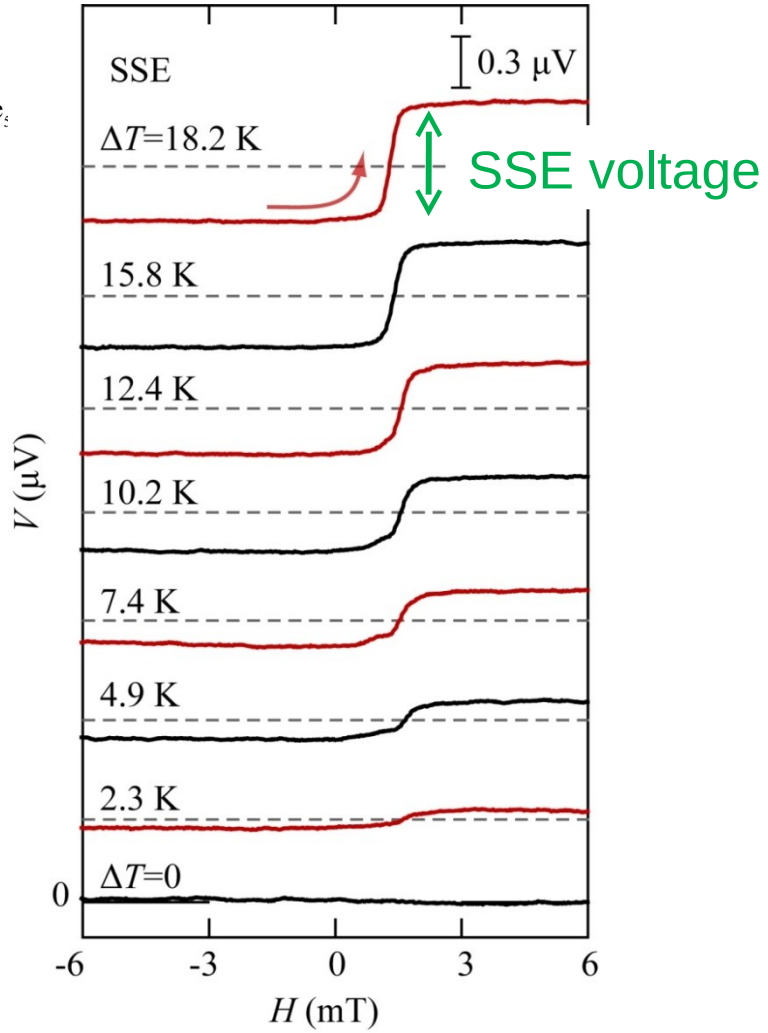
spin-Seebeck effect & Inverse spin-Hall effect





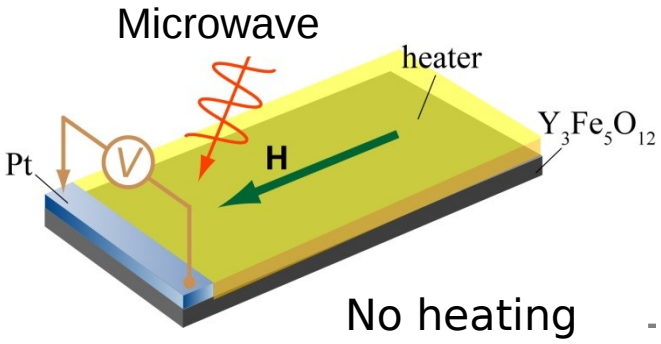
temperature gradient





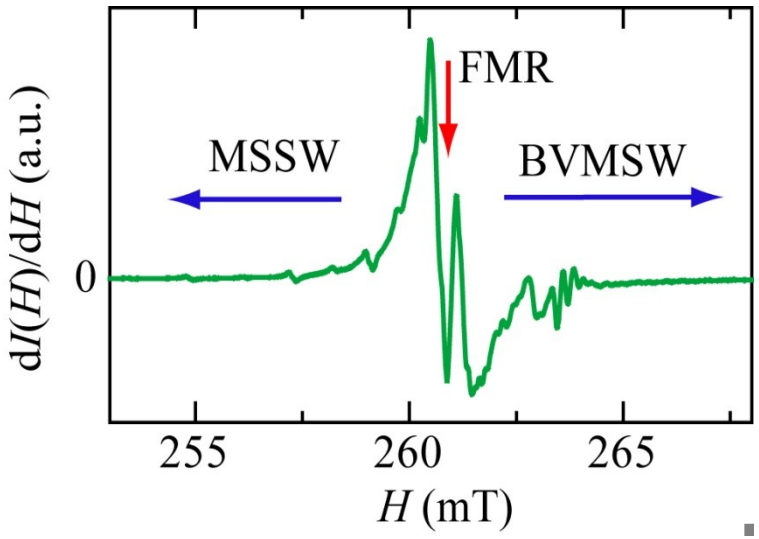
consistent with inverse spin-Hall effect and spin-seebeck effect model

H dependence of voltage induced by spin pumping



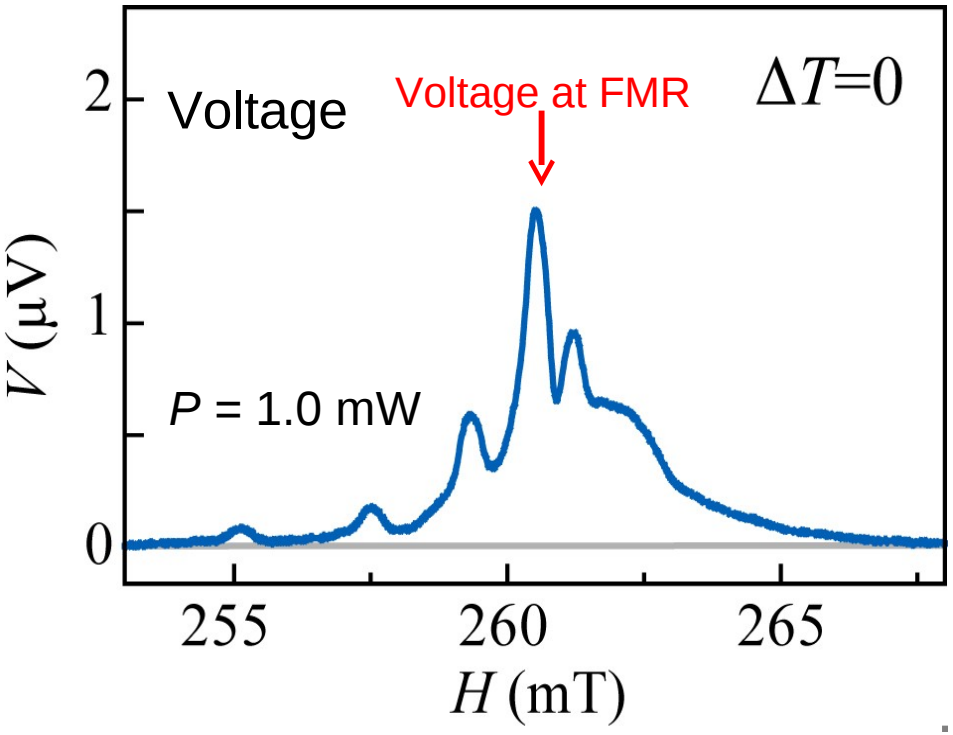
No heating

Spin wave resonance spectrum in YIG



assigned with MSW-SW

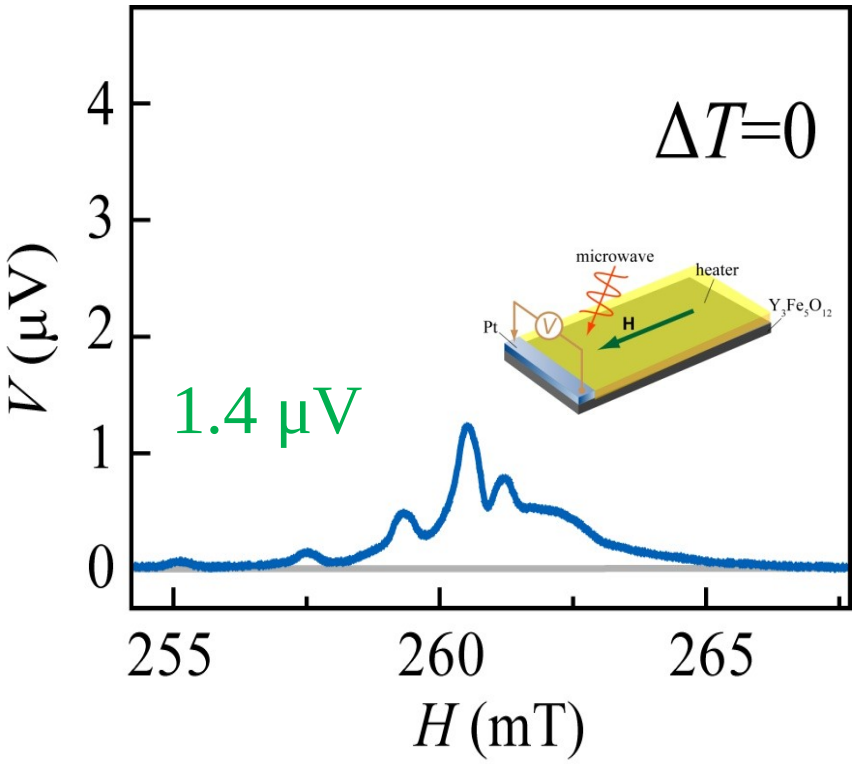
without
temperature gradient



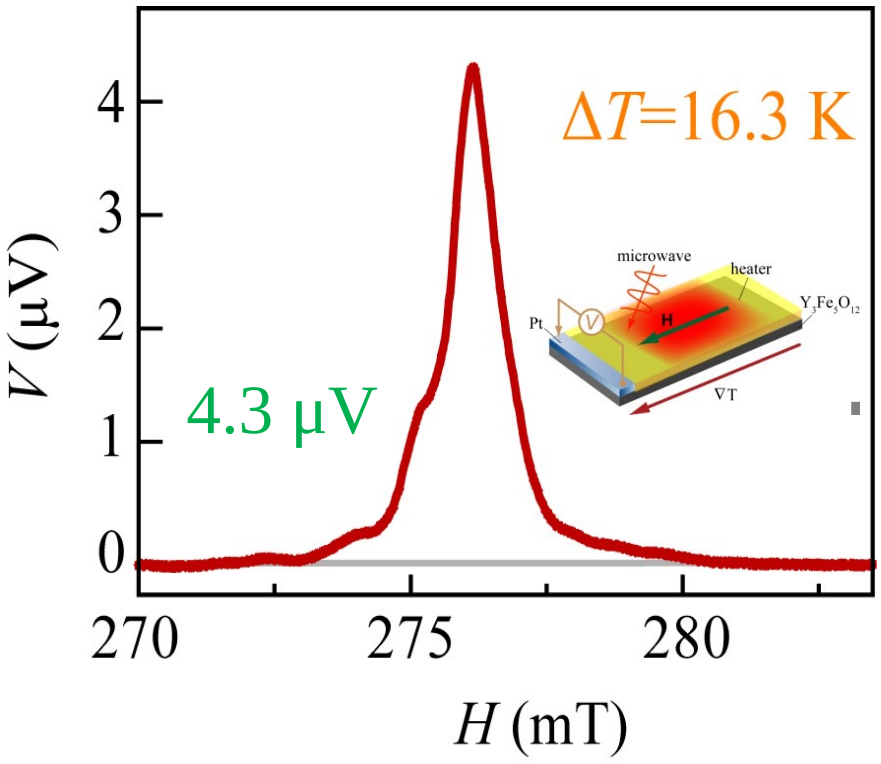
Electromotive force signal appears around spin wave resonance fields

H dependence of voltage induced by spin pumping

without
temperature gradient

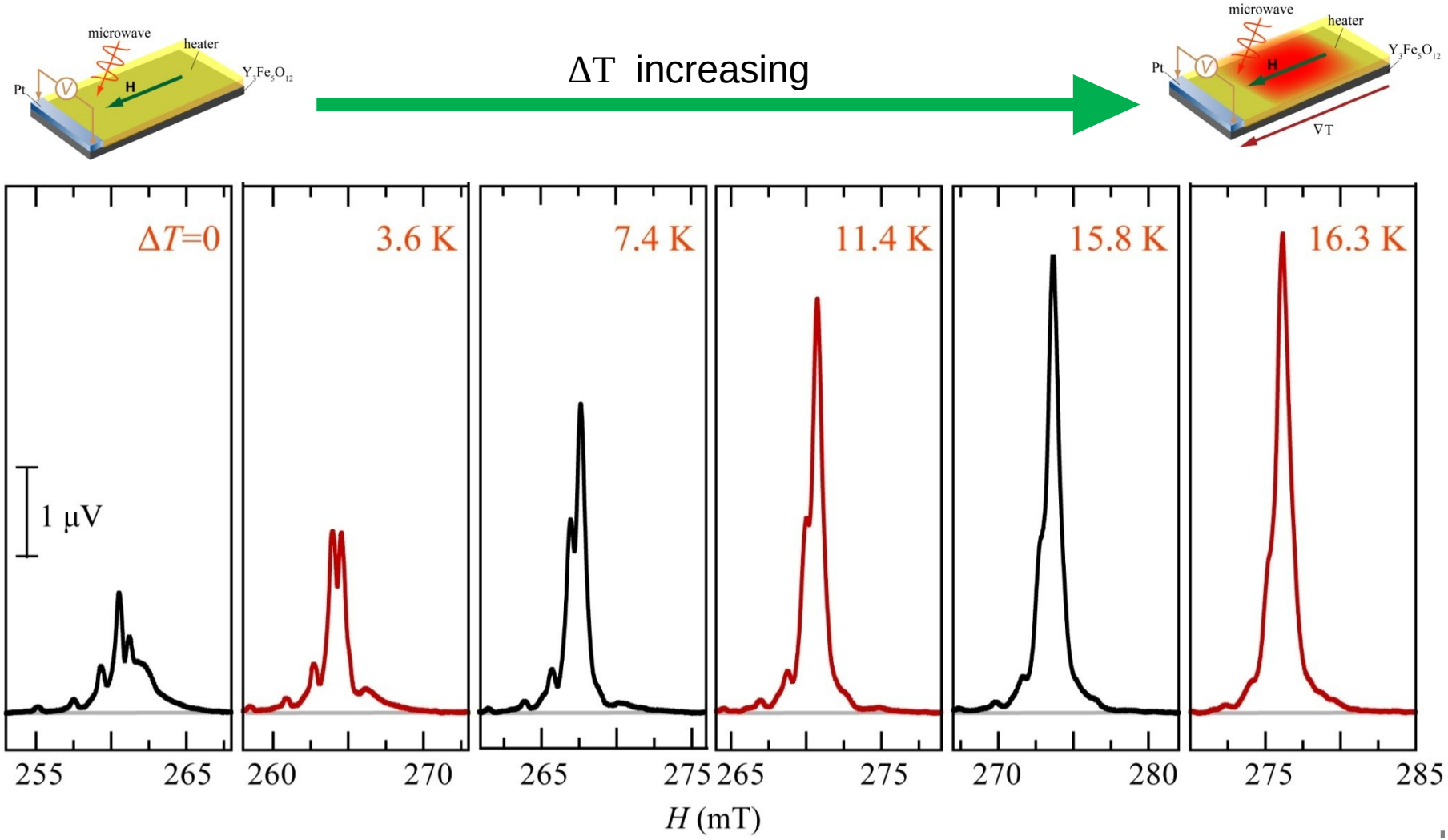


with
temperature gradient (ΔT =16.3K)



Spin pumping voltage is enhanced !!

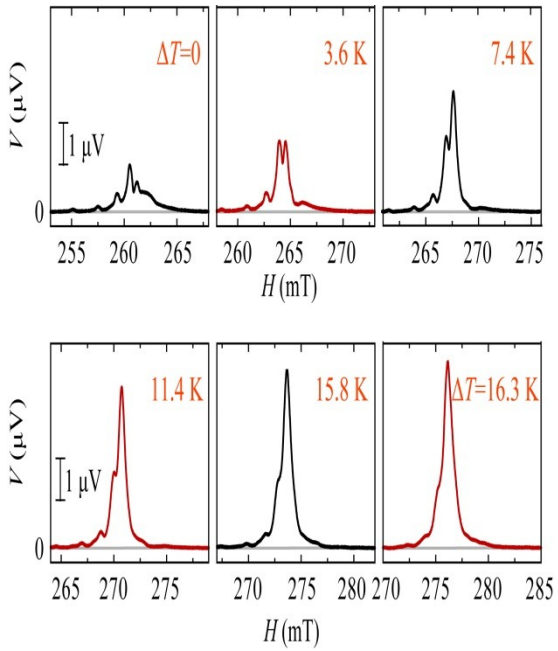
H dependence of voltage induced by spin pumping

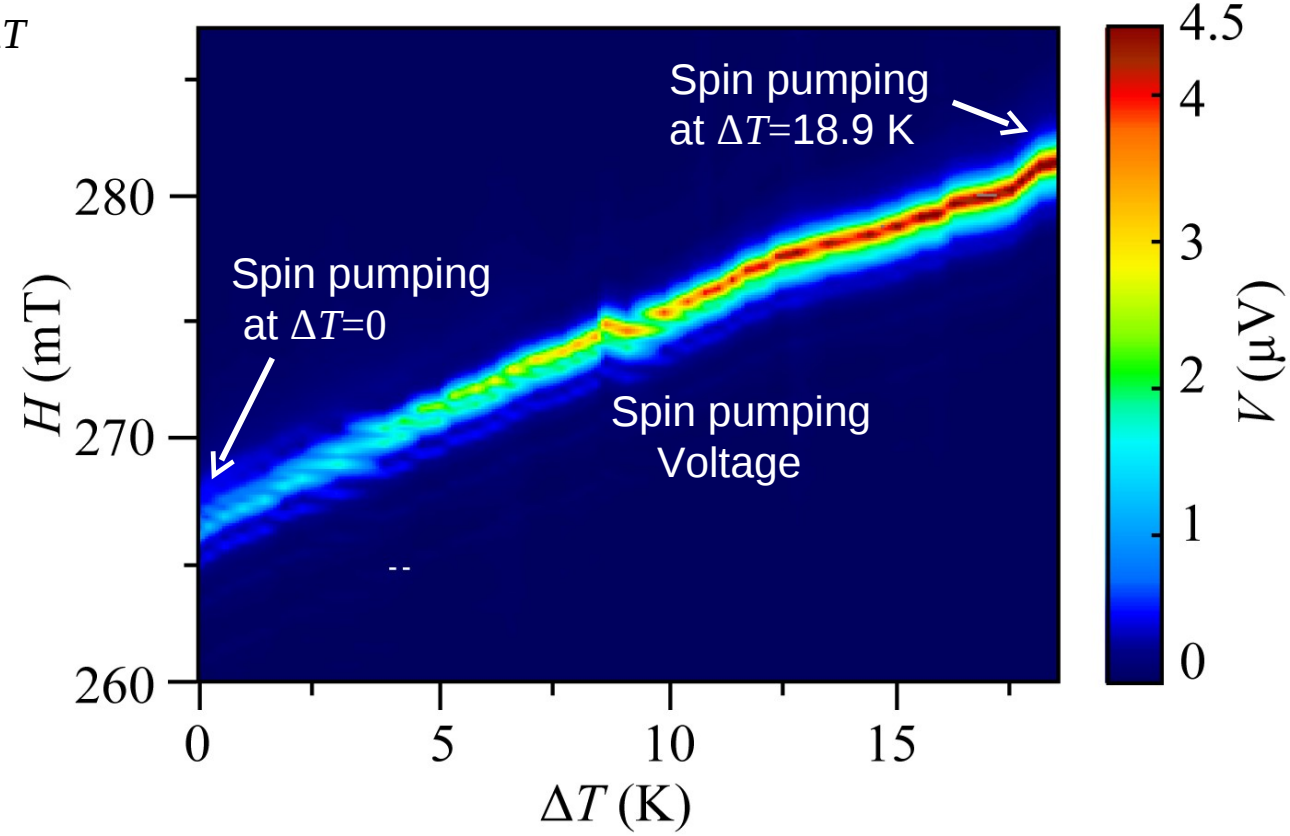


he amplitude of voltage generated by spin-pumping increas

H dependence of voltage induced by spin pumping

Voltage spectra with various ΔT

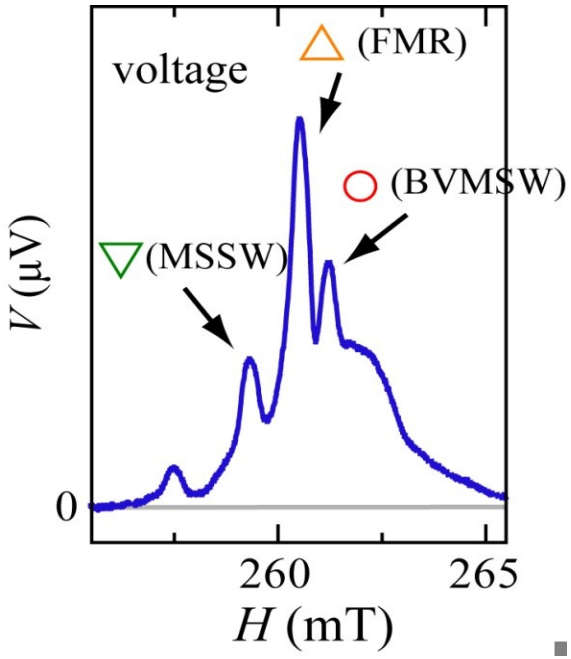


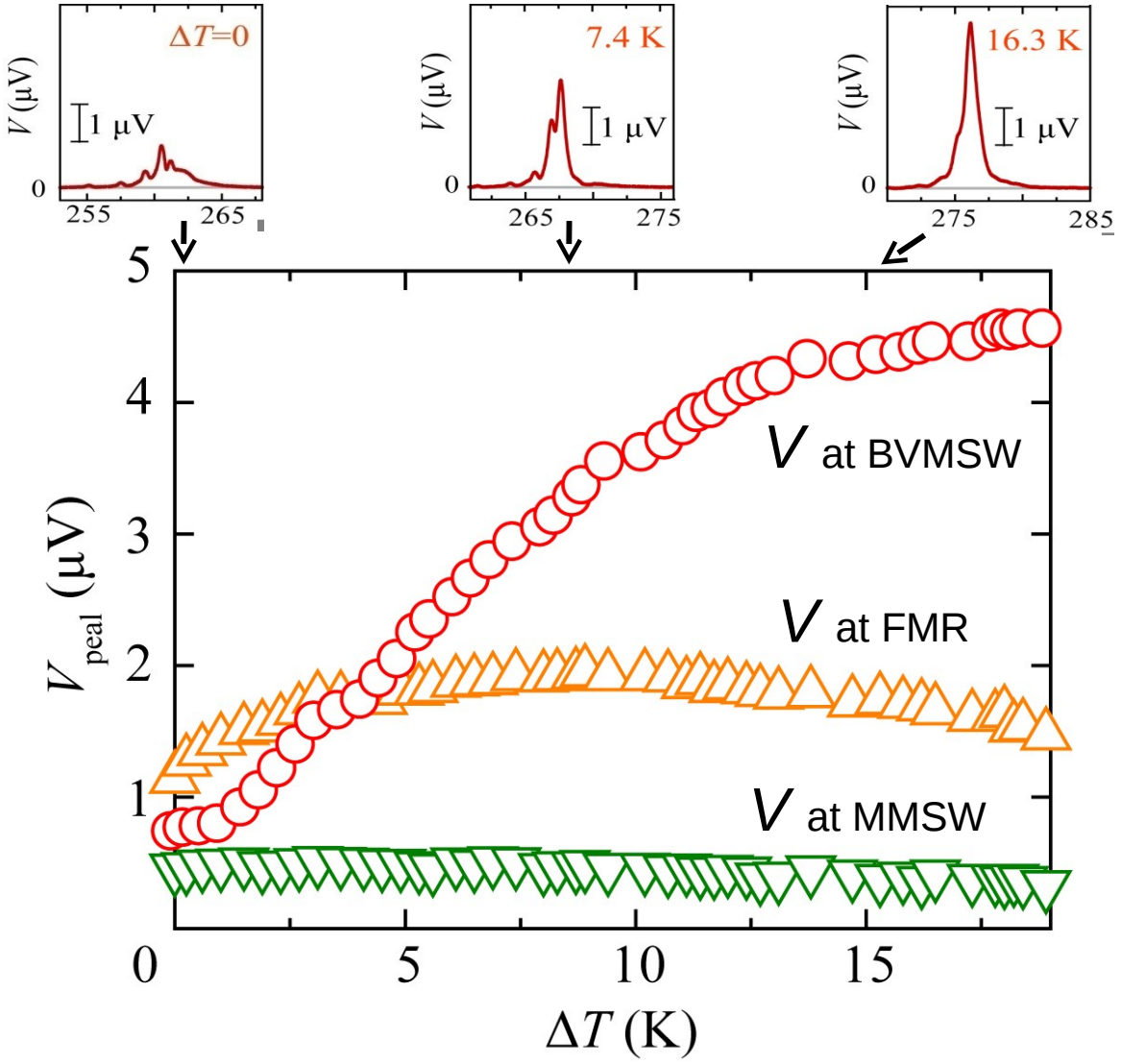


- Resonance field H_{FMR} changes (due to the heating effect)
- Voltage induced by spin pumping is enhanced

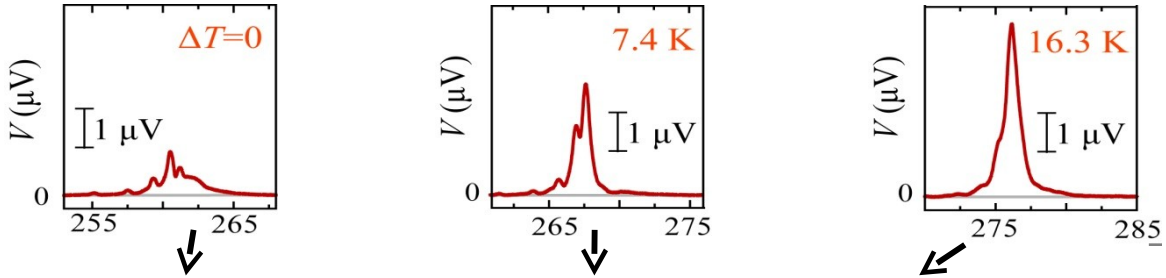
Temperature gradient dependence of voltage induced by spin pumping

Voltage spectrum at Δ=0 K

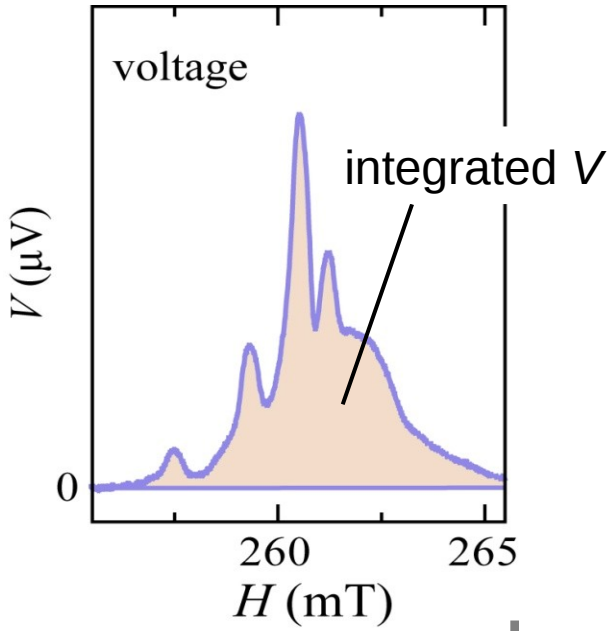


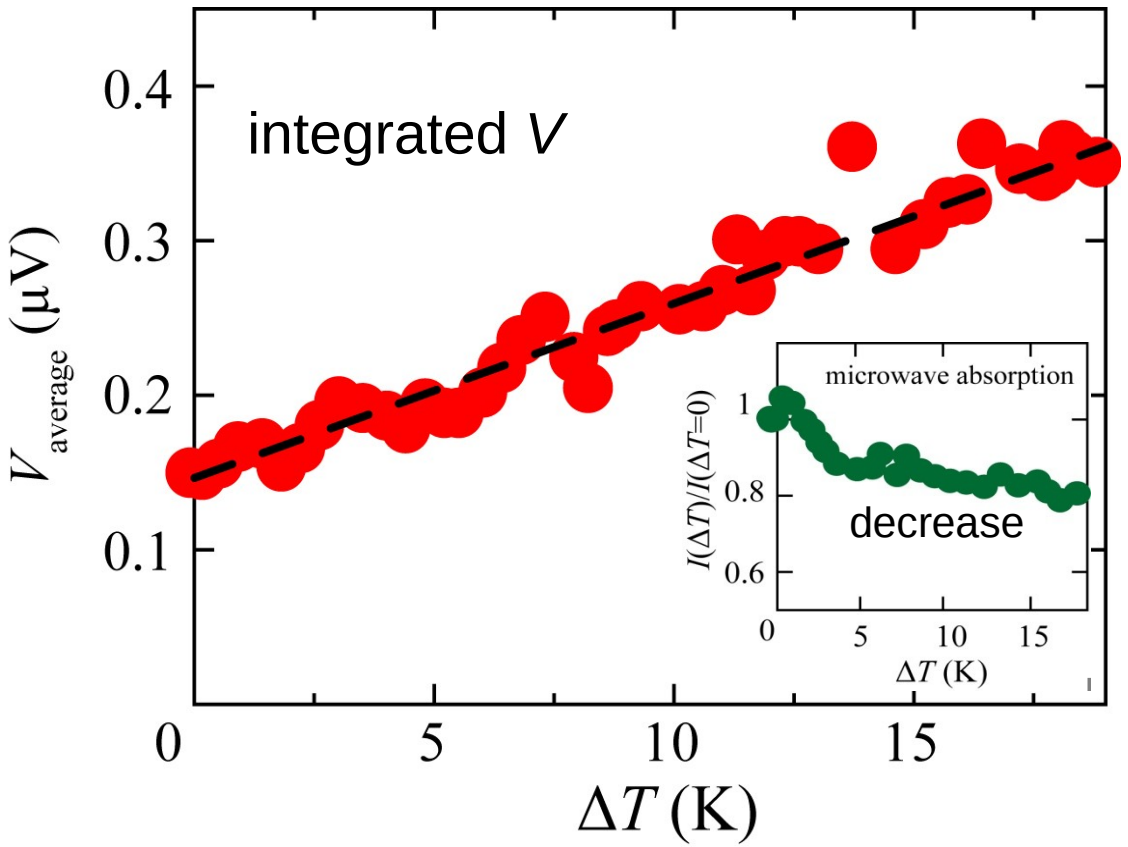


Temperature gradient dependence of voltage induced by spin pumping



Voltage spectrum at Δ=0 K

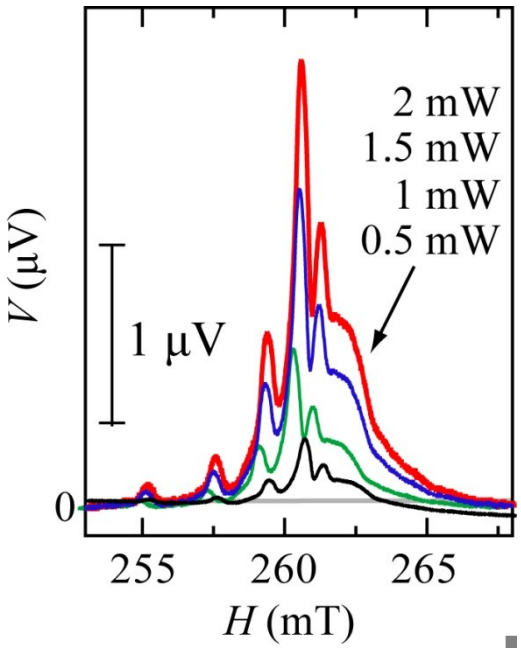


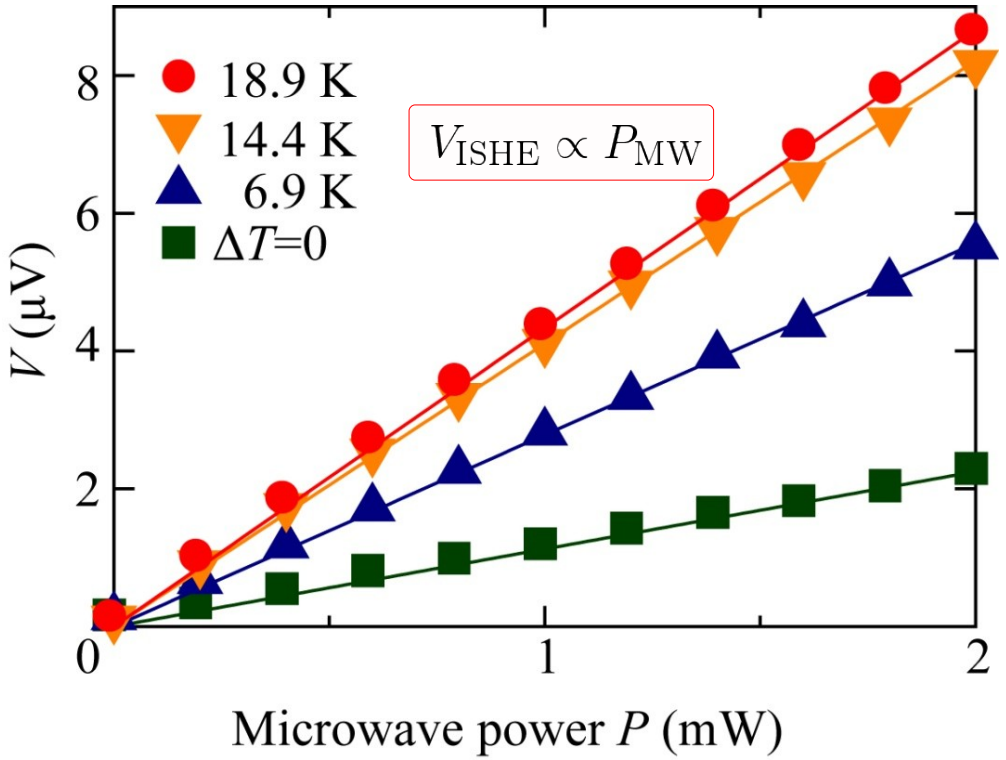


Integrated voltage $V_{average}$ monotonically increase

Microwave power dependence of voltage induced by spin pumping

Voltage spectrum at Δ=0 K





- the amplitude of voltage signal is proportional to emission-microwave power

consistent with ISHE and direct-current spin pumping model

Conclusion

By using a bilayer film comprising Pt and single crystalline YIG with temperature gradient,

we found that voltage signal induced by spin pumping effect is enhanced due to the spin-Seebeck effect.