Toward optically addressing single rare-earth ions in solid state

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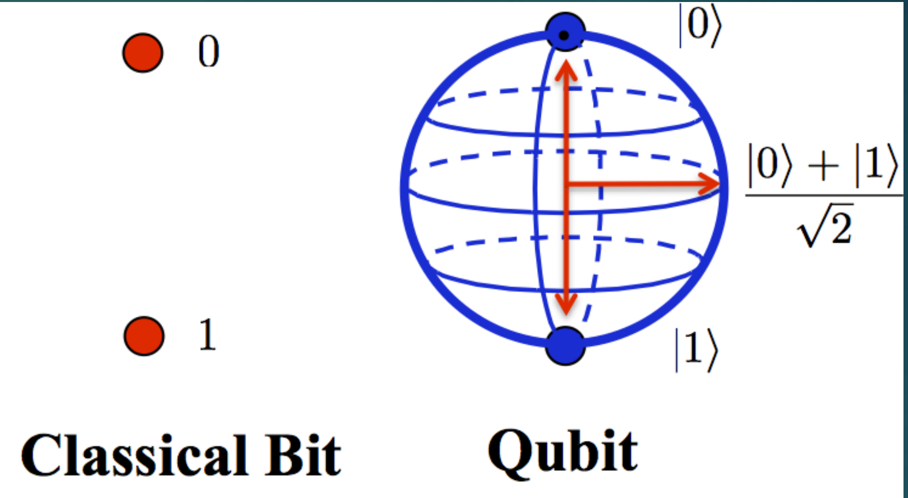
Motivation

- Rare earth ion as a candidate

  For quantum bits (qubit)
- Strong dipole-dipole interaction
- Long coherence time



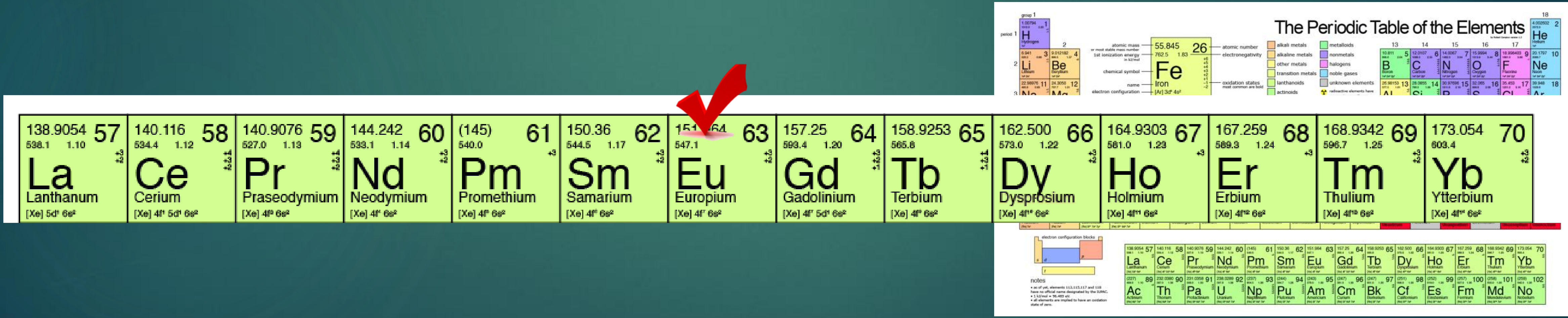


Image credit: http://qoqms.phys.strath.ac.uk/research_qc.html

The Rare-earth (RE)- Europium

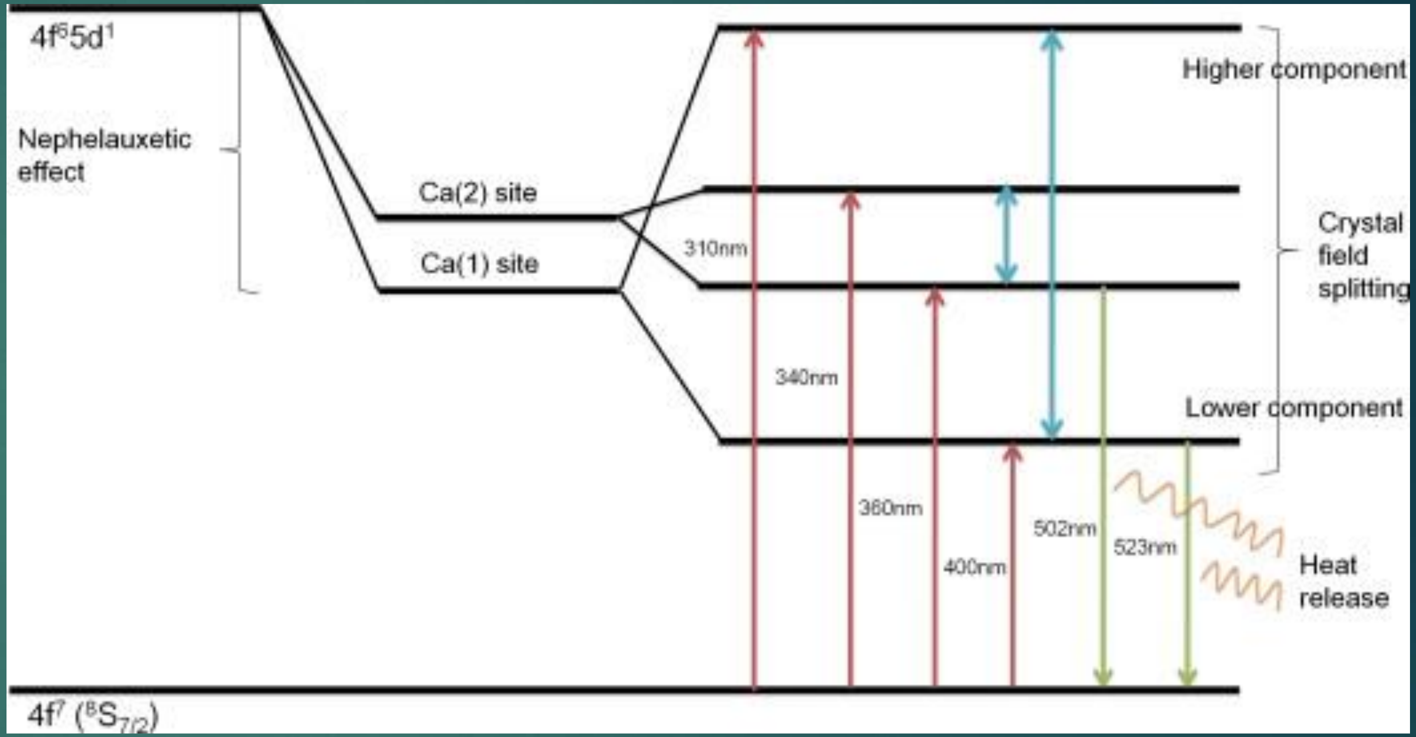
- Eu^{2+}
- In Ca_2SiO_4

^{40}Ca	^{44}Ca	^{42}Ca	^{48}Ca
^{28}Si	^{29}Si	^{20}Si	^{28}Si
^{16}O	^{18}O	^{17}O	

Eu2+: Ca2SiO4 is well studied at 0.1~1 mol % concentration

The energy level

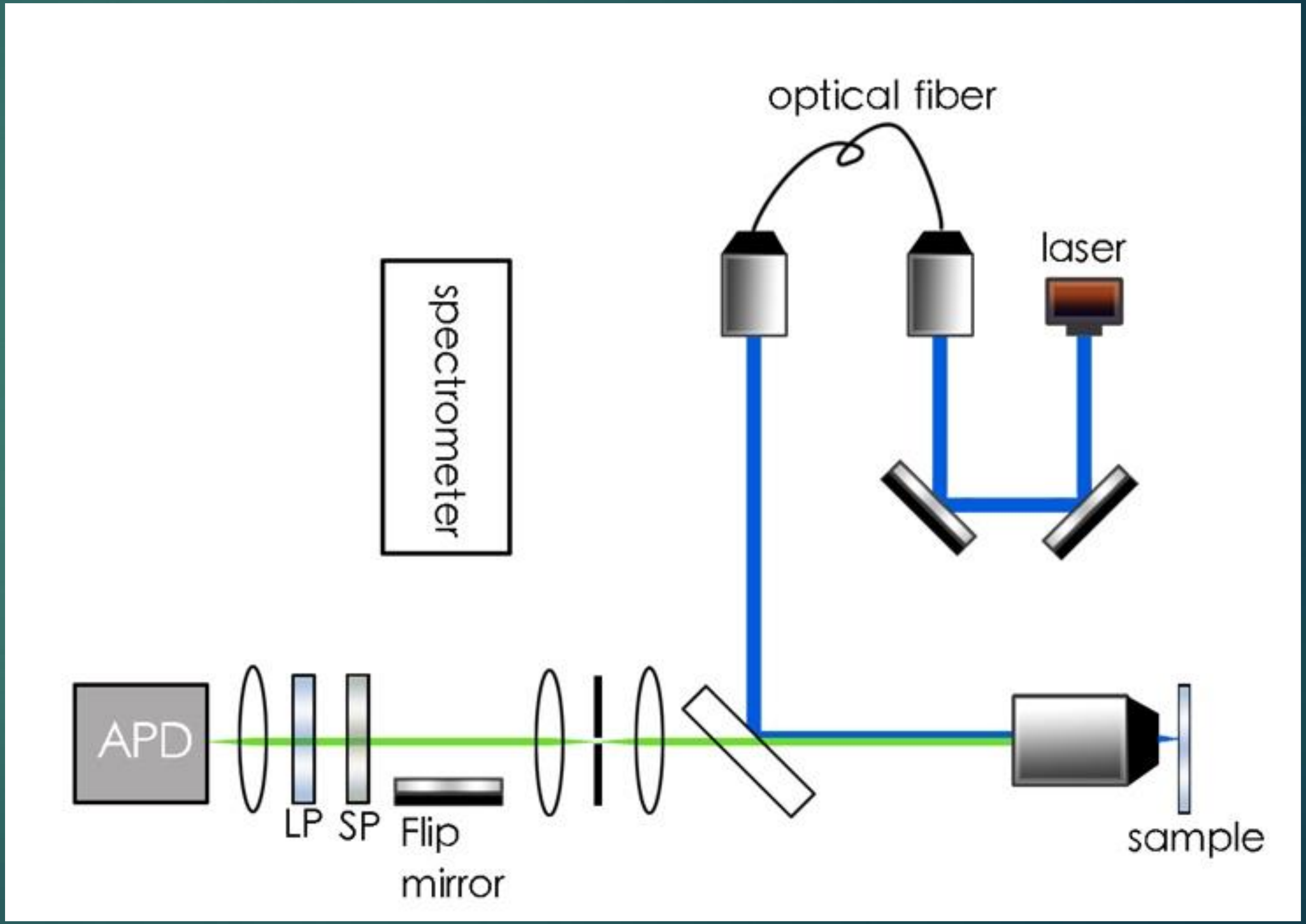
- $4f^65d$ $^8S_{7/2}$→$4f^7$ transition
- Crystal splitting
- Occupying either
  Ca(1) or Ca(2) Site



credit: Y. Y. Luo, D. S. Jo, K. Senthil, S. Tezuka, M. Kakihana, K. Toda, T. Masaki, D. H. Yoon, J. Solid State Chem. 2012, 189, 68 – 74.

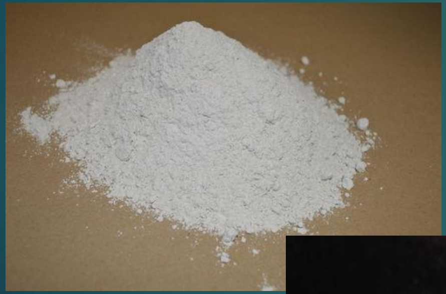
Setup

- Diode laser (405nm)
- Short pass 625nm
- Long pass 450 nm



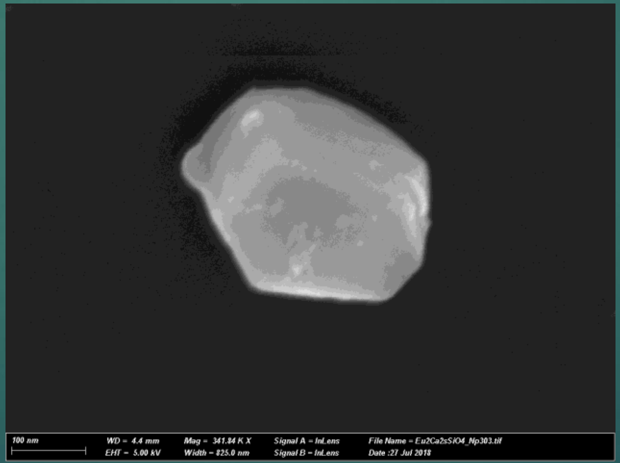
Crystal producing and Ion stabilization

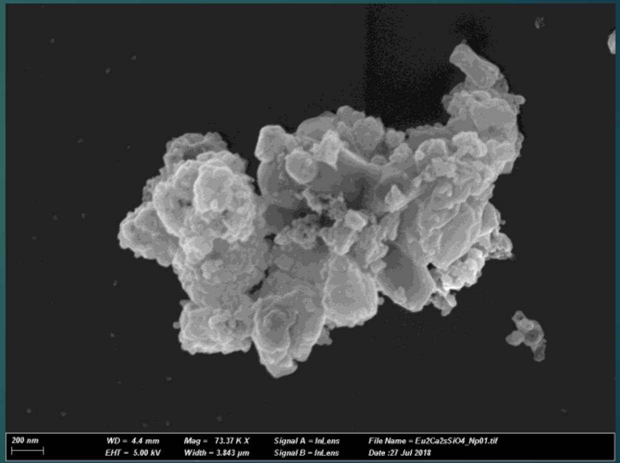
- Solid State Reaction
- Trivalent to divalent
- Reduced atmosphere



Crystal producing and Ion stablization

- Bad crystal that bleached or blinked
- Under Scanning electron microscope
- Annelaing temperature matters



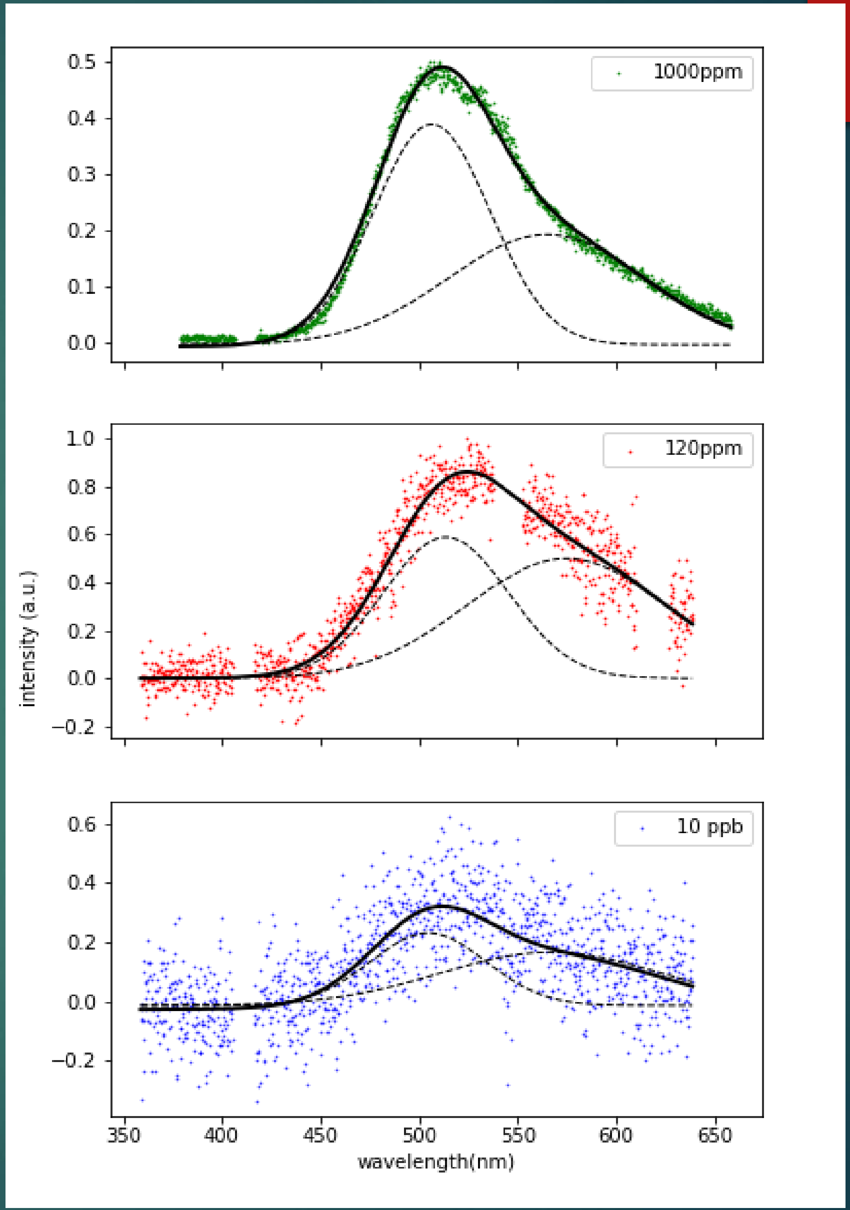


Spectrum

- Broad (multi)band
- Two Gaussian profile

Red-Shift!

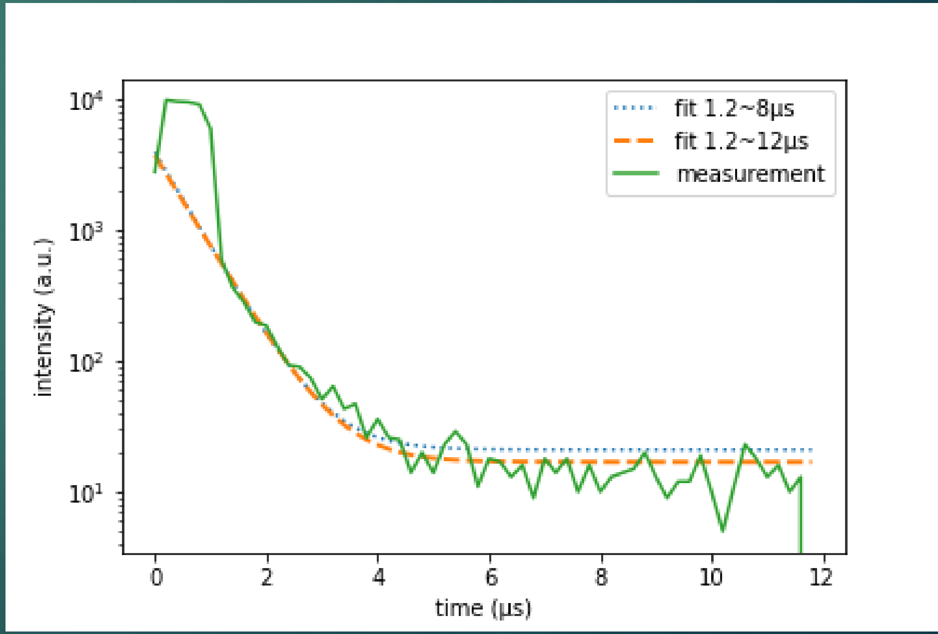
	Ca(1)	Ca(2)
1000 ppm	562.28(0)	504.76(7)
120 ppb	575.75(6)	510.96(0)
10 ppb	595.92(4)	514.76(0)



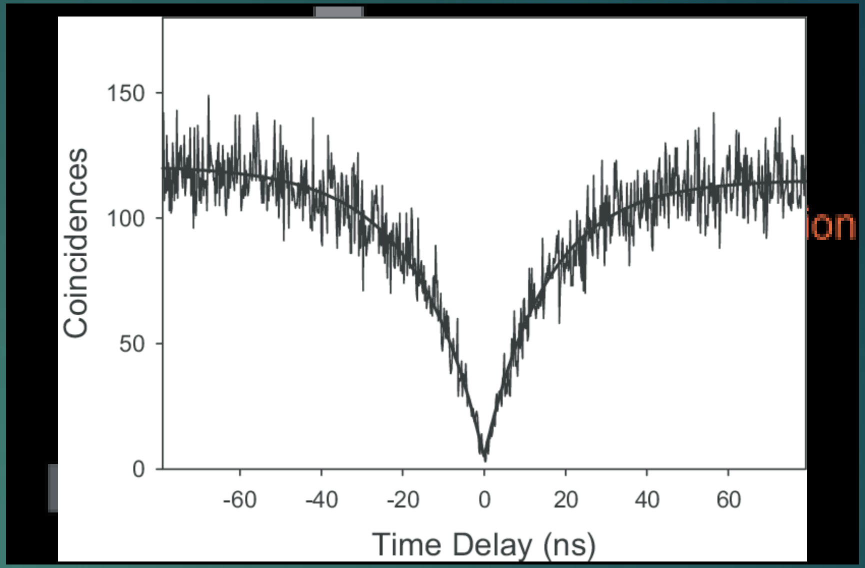
Fluorescence Life time

- 0.62(1) μs
- All photons within the wavelength window is collected
- longer than the previously reported fluorescence lifetime (0.53 μs)
- As expected…

**But an unknown fast-decaying source
Is causing trouble!**



Future work



- Anti-bunching measurement
- Increase the yield of good crystals
- OR do ion implantatioin instead

Picture credit: /wiki/Hanbury_Brown_and_Twiss_effect;

Future work

- As for verifying that the nano crystal indeed contain something close to SINGLE Eu^{2+} befor setting up the Hanbury Brown and Twiss…
- Maybe we need photon statistics…
- How about just look at the spectrum?

$$P(n) = 2^{(-n+1)}$$

Future work

- Even if we do not reach single ion level… (proposed by Dr. Kolesov)
- Find the optical transition at cryogenic temperature

Many thanks to…

- Prof. Mingchung Chu, Prof. Sen Yang and Prof. Dajun
- Prof. Dr. Jörg Wrachtrup, Dr. Roman
- Thomas Kornher, Stephan Hirschmann, Dr. Rolf Reuter, and Ferdinand Schiller
- $$$ the Department of Physics, CUHK $$$

Thank you for listening!

Reference

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Q&A time