

Spin-based millikelvin microwave quantum devices

Yuimaru Kubo

Ching-Ping Lee, Morihiro Ohta, Hiroataka Terai
Science and Technology Group

What is the problem?

The tremendous development of quantum computing R&D has attracted investment from big IT companies such as Google, IBM, Microsoft, Amazon, and Alibaba. The superconductor- or semiconductor-based quantum computing hardware systems are the leading platforms, especially in terms of scalability. Importantly, these systems operate at microwave frequencies and in a millikelvin temperature environment in a special but commercially available refrigerator called a dilution refrigerator. Amplification of microwave signals at millikelvin temperature without adding noise is one of the essential keys to quantum computing and related technologies. However, the current state-of-the-art device, the superconducting Josephson parametric amplifiers, suffer from a limited saturation power of about 0.1 picowatts. Furthermore, they stop operating even under modest static magnetic fields of ~ 10 millitesla.

What is your solution?

To challenge these issues, we develop a new cryogenic ultra-low noise amplifier based on the stimulated emission of impurity spins in gem crystals. We achieved the first proof-of-concept demonstration using paramagnetic impurity spins in a diamond crystal placed in a microwave resonator at around 6 GHz (see Fig. 1). However, the amplifier's bandwidth is relatively narrow (~ 100 kilohertz) because of the microwave cavity, which limits the gain-bandwidth product of the maser amplification. To mitigate this bandwidth problem, in this POC project, we will realize a spin-maser device in a traveling-wave geometry (see Fig. 2), and an overwhelming performance (more than a power gain of 100 with about a bandwidth of about gigahertz, and a saturation power of microwatt or more) is expected. The new technology may lead to a paradigm shift for cryogenic microwave quantum technologies, particularly for the qubit integration or detection circuit design. Besides, the maser amplifier may be implemented as the first amplifier in a magnetic resonance spectrometer, such as electron spin resonance, which may also significantly enhance the detection sensitivity.

Keywords: Quantum technology, quantum computing, quantum sensing, quantum engineering, magnetic resonance

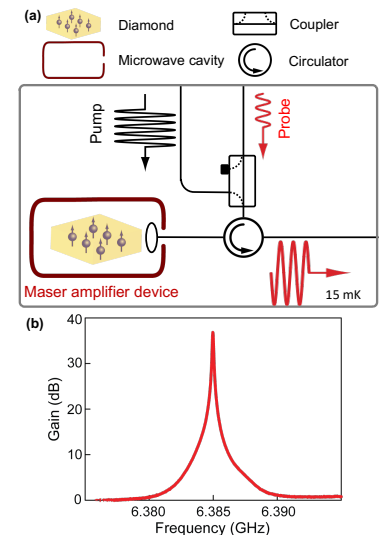


Figure 1. The first demonstration of maser amplification at millikelvin. (a) Setup schematic and (b) obtained gain (about 36 dB).

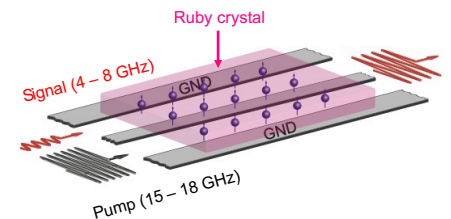


Figure 2. Schematic of the traveling-wave maser device. A broadband two-dimensional microwave waveguide is interacted with spins.

Other resources

- [Patent information](#)
- [Group website](#)

Contribution to SDGs



For more information:

rdcluster@oist.jp