A new technology for detecting microwave radiation will help in space exploration and quantum computing. The technology was developed in the Shulich Faculty of Chemistry at the Technion.

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Chemistry

Microwave radiation is a common phenomenon in nature and in many artificial devices. It is radiation whose wavelength is on the spectrum between a millimeter and a meter. One of the dramatic manifestations of such radiation in nature is the cosmic background radiation, which was discovered in the 1960s and provides a lot of information about the big bang that produced it.

Prof. Aharon Blank (right) and Dr. Alex Sherman

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In everyday use, we are particularly familiar with the microwave device, which allows us to heat food at high speed, but waves of this type are also used in other fields, including cellular communication, deep space communication, dark matter detection, as well as devices for quantum technologies (communication, computing and sensing).

Many of the advanced technological applications are based on very weak microwave signals, the detection of which in real time is a very complex technological challenge.

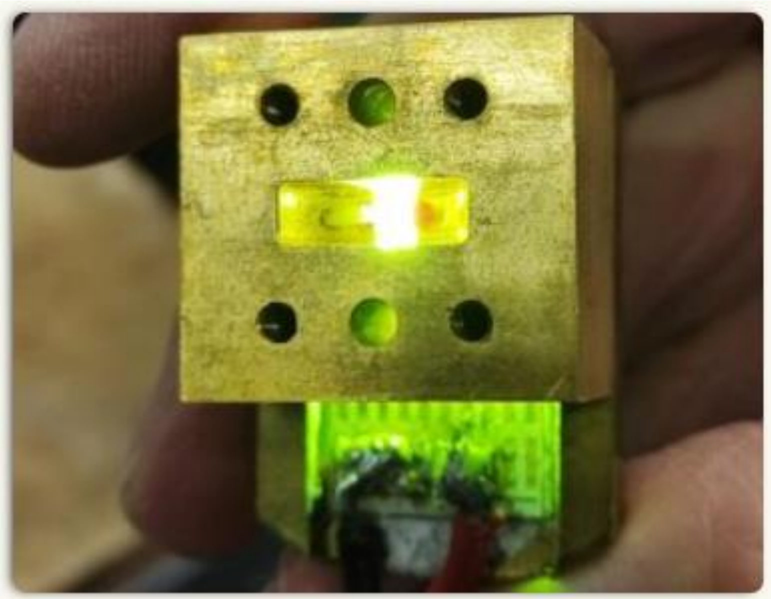
Therefore, many research groups are working on developing ways to amplify microwave radiation. It is of course important that this gain does not add significant noises that would interfere with the reproduction of the original signal.

Today there are already several effective technologies for amplifying and detecting weak microwave signals, and some of them make it possible to detect even a single microwave particle (photon), but they require the use of superconducting materials cooled to a temperature of about 10 millikelvin. Another possible technology is a maser - a device similar to a laser but based on microwave radiation. This technology, which was already developed in the middle of the 20th century, has many advantages, including extremely low noise and resistance to strong pulses of microwave radiation. This technology was used, among other things, to detect the cosmic background radiation as well as to communicate with spacecraft outside the solar system. However, maser technology requires cooling the system to a temperature close to absolute zero, since when masers operate at a temperature above 1 Kelvin, they create a lot of noise that does not allow for accurate and reliable information about the original microwave radiation.

These two shortcomings - temperature and noise - are answered in a study published by the Shulich Faculty of Chemistry researchers in the journal Science Advances. The study, which was done as part of Dr. Alex Sherman's doctoral thesis under the guidance of Prof. Aaron Blank, presents a relatively quiet maser device that operates at temperatures which are higher than the boiling point of nitrogen (-195.8 degrees Celsius), i.e. well above 1 Kelvin. The maser is based on diamond crystals and one of the defects that characterize them - Nitrogen-vacancy center. Diamonds are carbon atoms compressed under high pressure and thus fixed in an ordered crystal, and the aforementioned defect includes a nitrogen atom that replaces one of the carbon atoms and next to it the absence of a carbon atom where it is "supposed" to be. This defect has unique properties that researchers have exploited to make it an efficient and noiseless maser that amplifies microwave signals.

According to the researchers, the new device can be used to demonstrate additional phenomena such as multiple echoes and super radiation, which may be essential in quantum electrodynamics, and it can also be used as an oscillator - a wave generator. In their estimation, the aforementioned development will lead to new achievements in quantum science, engineering and various physical applications.

Green light absorbs the nitrogen vacancy defects in a diamond crystal that is emitted in a metallic resonator and enables the operation of the quantum microwave amplifier with low noise (see picture).



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