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Room-Temperature MASERs for Ultra-low noise devices

MASERs allow signals at microwave frequencies (0.1-100 GHz) to be amplified with unparalleled low electronic noise, allowing applications both as a receiver for deep-space communication, radar and medical imaging, and as a frequency standard for atomic clocks.

Proposed use

Although MASERs can offer amplification of microwave signals with unparalleled low electronic noise in a range of electronic and medical devices, historically they required cryogenic cooling and hence never reached mass production.

However, the discovery of MASERs that can work at room temperature completely transforms the approach and paves the way for exploitation. Already we can foresee additional applications for the re-engineered MASER that include more sensitive medical scanners; chemical sensors for remotely detecting explosives; portable atomic clocks; advanced quantum computer components; and better radio astronomy devices for deep space exploration.

Problem addressed

Engineering electronics that are resistant to noise is technically possible but has always been costly. One early promising noise-limiting technology was the MASER, discovered by Charles Townes in the 1950s and a sister technology to the laser.

Yet, the MASER has had little widespread technological impact because it was inconvenient to use - only functioning in high magnetic fields, a vacuum and at temperatures close to absolute zero (-273°C). It was just too difficult so it was not surprising that Townes and his team turned to LASERs which could operate in the earth's magnetic field and at room temperature.

MASERs *did* see continuing use where the unmatched noise properties were essential, e.g. for radio astronomy, and now room-temperature masers offer this luxury of low noise without the cost in maintaining the necessary conditions for operation.

We have a discovered a new design for a MASER that overcomes these problems. The performance of this new MASER is orders of magnitude better than the best competing technology. The breakthrough means the cost to manufacture and operate MASERs could be dramatically reduced, paving the way for their widespread integration into telecommunications.

Technology overview

MASERs can amplify tiny signals and increase signal-to-noise as very low noise amplifiers – these are found in all manner of electronic equipment, but our noise floor is 2-3 orders of magnitude lower than the best semiconductor amplifiers (high electron mobility transistors or HEMTs) available today. MASERs could thus facilitate clearer images in a MRI machine or alternatively match current standards with lower acquisition times.

If we follow of the history of the LASER and its applications, we can see that a coherent source of microwaves opens up many new applications in radar, microwave computerised tomography and microwave imaging that are not possible with current incoherent sources. This means that in air or ground penetrating radar, the shapes of targets could be more recognisable; the possibilities of more detailed physiological medical data could be recorded and new medical imaging modalities invented.

Benefits

- A MASER that can act both in pulsed mode or continuously at room temperature.
- Potential applications: quantum radar, medical applications, low noise devices, quantum information processing and other applications.
- The technology could be used in a range of applications, such as medical imaging, airport security scanning, deep space communication and radio astronomy.
- MASERs could play a pivotal role in improving sensors to remotely detect bombs or new technology for space communication.
- Highly portable precision clocks that could maintain local synchronisation with satellite navigation systems when satellite signals are obstructed.
- Possible applications are for low noise amplifiers and communications requiring low phase noise
- Non-destructive microwave applications

Dr Valeska Gonzalez

Executive, Industry Partnerships and Commercialisation - Faculty of Engineering

e: v.gonzalez-montilla@imperial.ac.uk

t:+44 (0)7517551970

Technology references: **6199**, **7861** and **8016**

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The MASER group at Imperial have developed two MASER devices: a pulsed MASER using organic para-terphenyl crystals doped with pentacene molecules and a continuous MASER using nitrogen vacancy defects in diamond.

The pentacene MASER is suitable for detecting discrete signals (such as the microwave pulses used in MRI) and could operate as a Geiger-mode single microwave photon detector, while the continuous output of the diamond MASER make it particularly useful as a frequency standard, in addition to uses as an amplifier.

Intellectual property information

Device and method for generating stimulated emission of microwave or radio frequency radiation: European Application (Number: 13725742.4, Granted validated in FR, DE, GB) & US Application (Number: 14/403209, Granted).

- Imperial reference number **6199**.

Room temperature Masing using spin-defect centres.: European Application (Number: 18752220.6) & US Application (Number: 16/634225, Granted).

- Imperial reference number **7861**.

Apparatus and method for establishing quantum oscillations: European Application (Number: 17771845.9) & US Application (Number: 16/333254, Granted).

- Imperial reference number **8016**.

Inventor information

Professor Neil Alford
Professor of Materials, Department of Materials, Imperial College London

Dr Johnathan Breeze
Lecturer, Physics & Astronomy, University College London

Professor Chris Kay
Professor, Universitat des Saarlandes, Germany

Dr Enrico Salvadori
Associate Professor, Università degli Studi di Torino, Italy

Dr Juna Sathian
Senior Lecturer, University of Northumbria

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