

Microwaves trigger thermo-acoustic ultrasound generation

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Ultrasound is one of the most common modalities for diagnostic imaging of the body (biomedical imaging) and engineering structures (non-destructive evaluation–NDE). This is partly due to the lack of safety concerns when probing the body with acoustic waves and the availability and relative affordability of the equipment. Another very important strength of ultrasound is the penetration depth of ultrasonic waves into opaque materials. Frequencies in the low MHz range can usually penetrate deep inside tissue and other structures. However, ultrasound also has some drawbacks: in particular it usually has poor spatial resolution and requires the use of a range of special frequency band-limited transducers. There is on-going research work that tries to improve the spatial resolution by investigating techniques such as super-resolution algorithms,¹ micro-bubbles² and photo-acoustic (PA) imaging.³

PA imaging is a mixed technique that uses the high spatial resolution of electromagnetic waves in the visible or near visible part of the spectrum and the different absorption coefficient of structures inside tissue to turn the tissue itself into ultrasound sources. As strongly absorbing parts of the tissue heat up more than their surroundings they expand and emit a pressure pulse that travels through the tissue. The pressure pulse is then received by an ultrasonic transducer. This enables the formation of high-resolution images of internal structures that are captured at the outside of the body using ultrasound transducers. This technique is able to produce stunning images; however, it still relies on photons from an external source travelling inside the body and interacting with the tissue. Since the optical absorption of tissue is still relatively high, the penetration depth into the body is limited.

The work of Lan et al.⁴ was inspired by the work on PA and they investigated other means of thermo-acoustic generation of ultrasound. They focused on the use of microwaves, that can penetrate deeper into the tissue. By considering the physics of energy absorption and Poynting's relation of energy conservation, they stipulated that high intensity electric or magnetic fields are required to maximize the thermo-acoustic source strength. They then showed that a split ring resonator (SRR) is an effective way of increasing the magnitude of the electric field in a small spatial area, i.e. where a ring of a wire conductor

(roughly 13 mm diameter, 0.2 mm cross section) is split. They simulated and built a device that could be shown to induce local heating when it was excited with microwaves at about 2 GHz. They demonstrated local temperature increases of almost 70 K when the SRR was actuated by a microwave of 100 W power for 0.25 s. Furthermore, they demonstrated that the SRR was an efficient broadband ultrasound source and that it was possible to receive ultrasound signals with SNR ~30 that were produced when the SRR was placed inside a breast phantom and the microwave had to travel about 50 mm through the tissue-mimicking phantom.

The work therefore describes an interesting and promising concept to excite ultrasonic waves wirelessly over a relatively large range without any complicated circuitry. Nonetheless, at ~13 mm diameter the SRR is relatively large and it would be difficult to insert into the body. Therefore, for practical applications, it will be important to see if the concept can be adapted to build microwave resonator-based thermo-acoustic ultrasound sources with smaller spatial footprints. It is thus to be expected that the work of Lan et al. will act as a catalyst for further work in the field.

References

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