SPECTROSCOPY

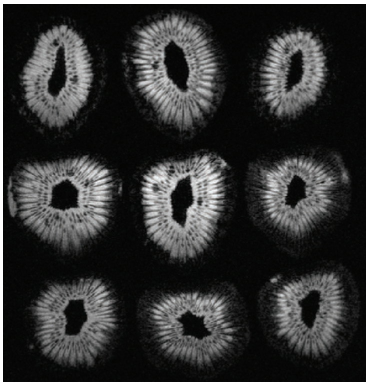
Don't just stand there

A long-range magnetic resonance imaging platform promises unprecedented capabilities for whole-organ visualization and high-throughput sample analysis.

Nuclear magnetic resonance offers a relatively safe and noninvasive means for achieving astonishing detail in biomedical imaging. Conventional magnetic resonance imaging (MRI) relies on a radiofrequency probe to generate detectable signals via the excitation of atomic nuclei that have been aligned within a strong magnetic field. However, in ultra-high magnetic fields—which yield maximum sensitivity—the required radiofrequency wavelength becomes so small that conventional detectors form standing waves in the human body. In large targets such as the head, this results in nodes that appear as blind spots in the images.

Klaas Prüssmann, a physicist at the Swiss Federal Institute of Technology Zürich, recognized that an alternative system based on the propagation of traveling radiofrequency waves would theoretically eliminate these nodes but was at a loss for how to implement such a system—until an insight by graduate student David Brunner led to a lucky break. While looking at a colleague's MRI images, Brunner noticed artifacts resulting from signals that appeared to be byproducts of wave propagation. After some calculations, Brunner realized that existing ultra-high-field MRI technology could be adapted for traveling-wave MRI. "The magnet that we used was not only very strong, at 7 Tesla, but also very wide, large enough to put in a whole human body," explains Prüssmann. "The diameter is a critical parameter, and the bore of this magnet was just wide enough to permit wave propagation at the [magnetic resonance] frequency."

Their approach also required an alternative mode of detection, in which the radiofrequency wave is propagated from an antenna positioned at one end of the cylindrical magnet; this wave travels through the specimen within the bore of the magnet, producing signals that are received either by the same antenna or by another one positioned at the opposite end. The resulting instrument considerably extends the scale of imaging possible with MRI, and initial tests demonstrated uniform high-field imaging of a variety of samples, both inorganic (vials of liquid) and organic (the leg of a human volunteer).



High-throughput imaging of kiwi fruits using traveling-wave MRI. Image courtesy of Klaas Prüssmann.

Prüssmann sees the greatest immediate value for this traveling-wave system in human imaging. "The most promising applications of ultra-high-field are in neuroscience studies where you need to see multiple parts of the brain at one time, and complete coverage is really essential," he says. However, this platform's capacity for uniform imaging of large-volume targets could also introduce unprecedented high-throughput capabilities to MRI for a variety of other research applications, ranging from materials analysis to laboratory animal screening. This method also offers the freedom to position the radiofrequency antenna surprisingly far from the sample—even several meters away from the magnet. This results in additional free space for the positioning of samples or additional equipment, but could also enable wholly novel experimental setups.

Cost may be an initial barrier to adoption of this platform—the massive, ultra-high-field magnets that make wave propagation possible can be prohibitively expensive. Nevertheless, this study represents powerful proof of concept for a new approach to a long-established imaging method, with considerable potential for future development. "The possibility of leveraging the power and sensitivity of very-high-field MRI in human applications for basically unhindered examination of full anatomies is the most exciting for us," says Prüssmann.

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RESEARCH PAPERS

Brunner, D.O. *et al.* Travelling-wave nuclear magnetic resonance. *Nature* **457**, 994–998 (2009).