

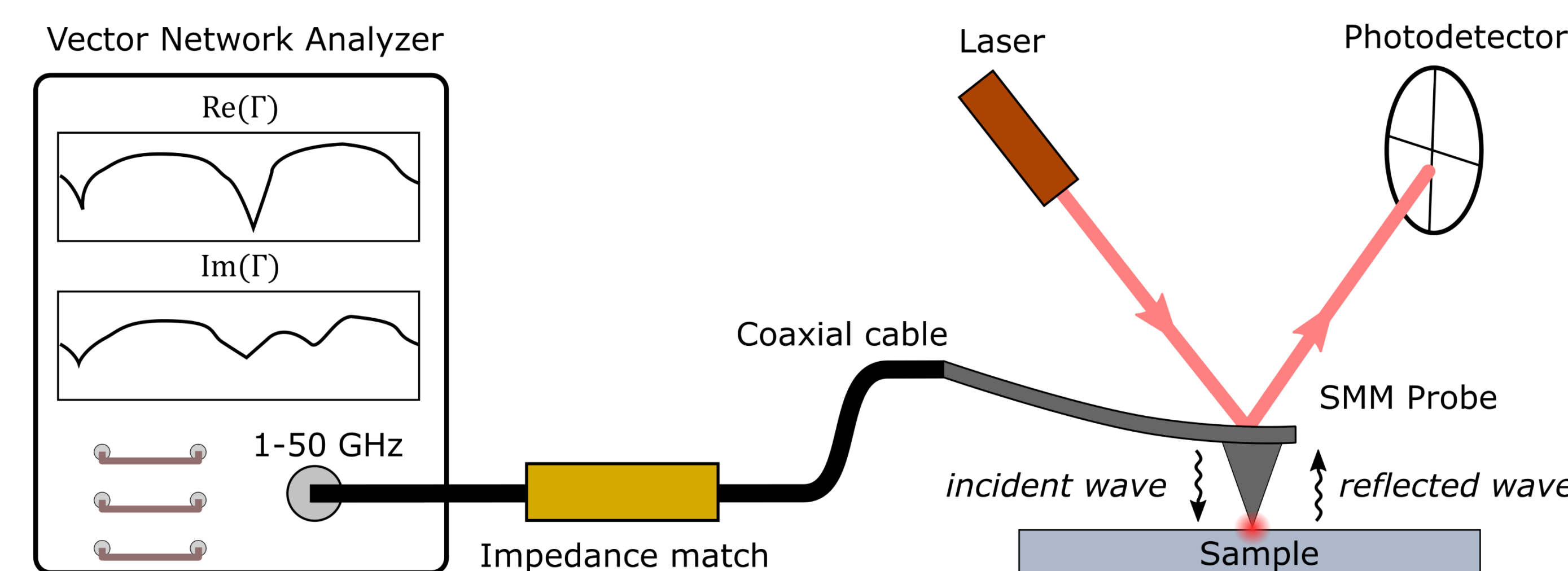
Scanning Microwave Microscopy for Biomedical Applications

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In **Scanning Microwave Microscopy (SMM)**, a sample is probed for its electrical properties using **near-field** microwave signals. Here, a novel type of **scan head** is presented which is potentially suitable for measuring **biological tissues** and permitting a **high degree of automation** due to its robust design. Example measurements on a **pig brain** are demonstrated.

Working Principle of SMM

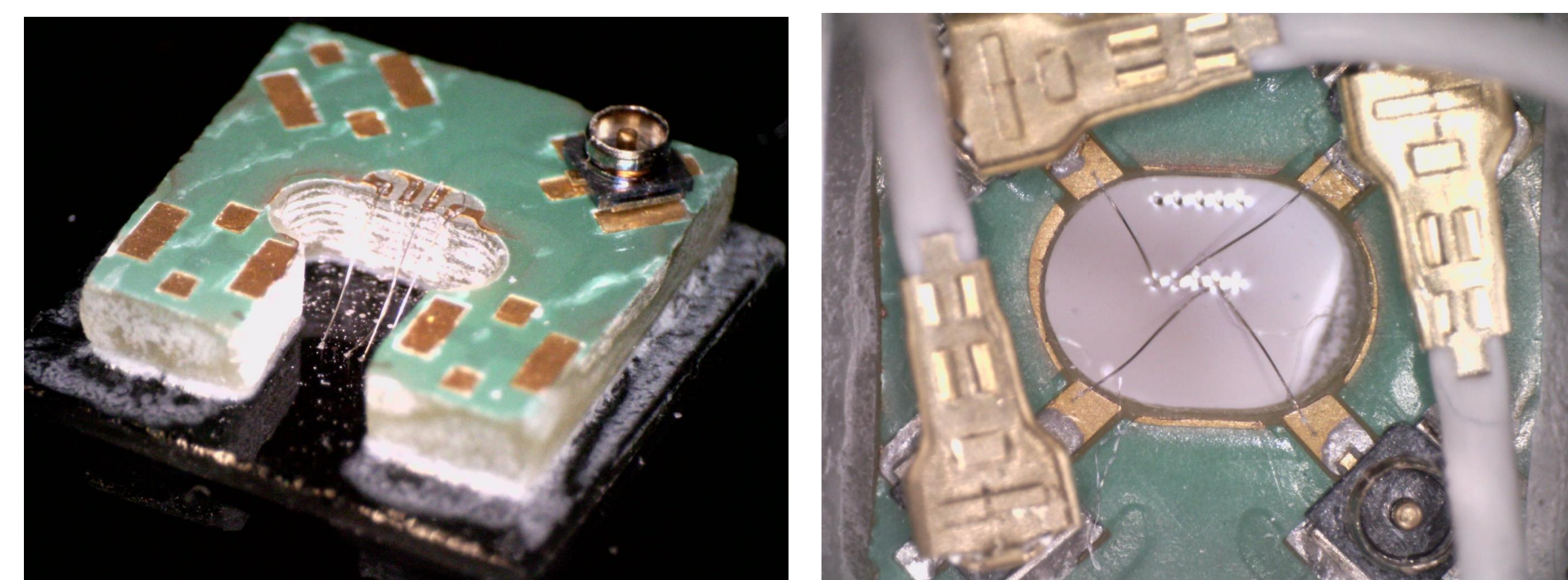
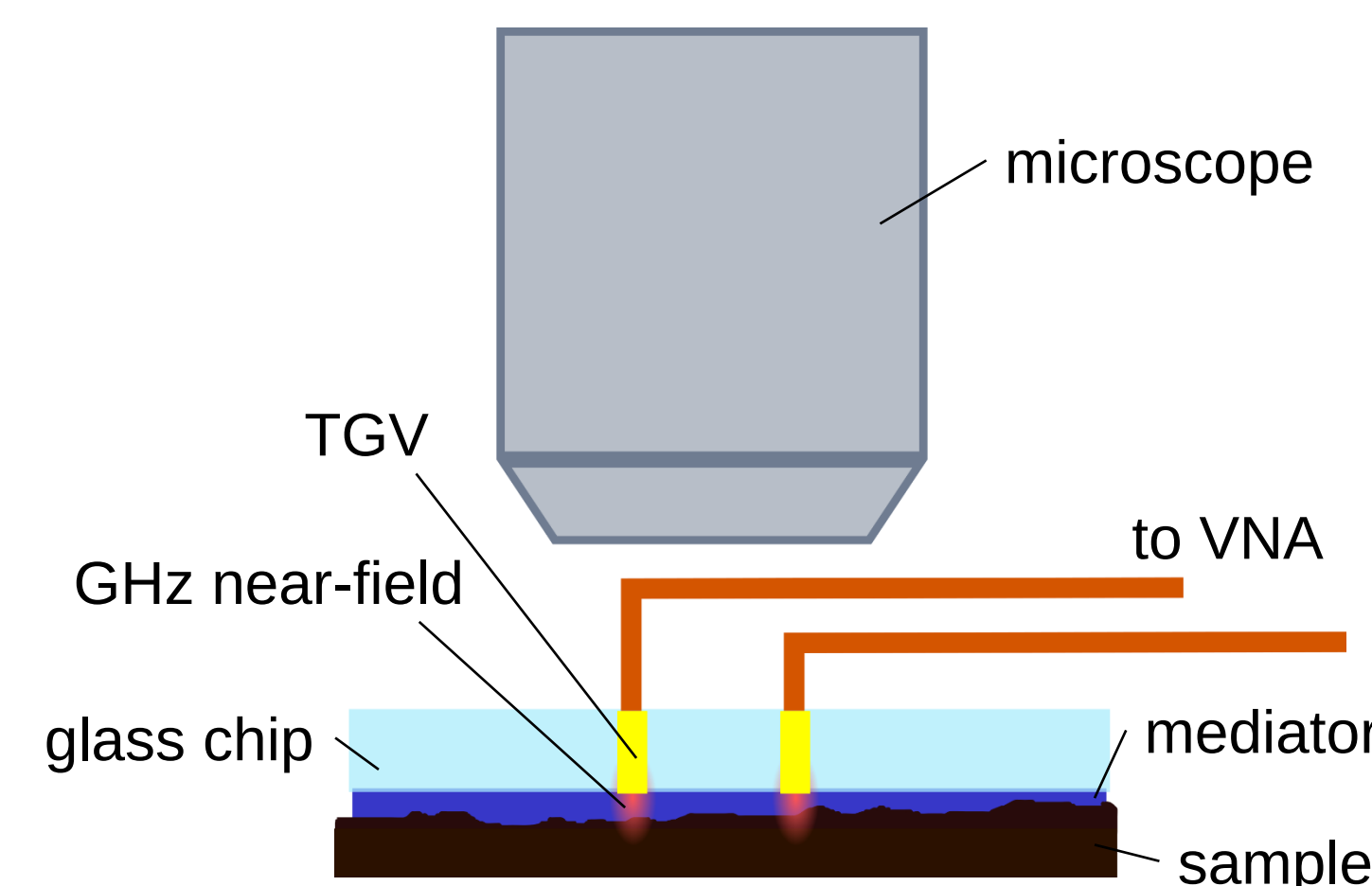
A **microwave** signal is generated by a **vector network analyser (VNA)** and fed through a coaxial network into the measurement probe. The signal gets reflected at the probe-sample interface and is measured again by the VNA. The measured **complex reflection coefficient Γ** provides information on the **capacitive** and **resistive properties** of the sample. A **2D map** of the sample properties is recorded.



A **conventional SMM** uses a very fine metallic tip mounted on a cantilever. The tip-sample distance is controlled by analysing the deflection signal from a laser captured by a photodetector. This technique provides high lateral resolution, but is fragile in operation, relatively slow, and difficult to automate.

A Robust Scan Head

- Metallic through-glass-vias (TGVs) are incorporated into a glass chip and act as measurement probes
- The multitude of probes allows parallel data acquisition
- The transparent glass chip allows sample observation and optical distance control with a microscope
- A mediator layer (e.g. water, oil) is added to increase the signal-to-noise ratio
- A PCB hosting a coaxial connector is glued onto the glass chip (1 x 1 cm²)
- Four TGVs ($\varnothing = 100 \mu\text{m}$) are wire-bonded to the PCB
- The glass encapsulates the probes and protects them in harsh physical or chemical environments
- Top view through the microscope onto the glass chip
- Four of the ten visible TGVs (dots in the centre) are wire-bonded to the PCB
- Coaxial cables (gray) are connected, transferring the signals from the VNA to the TGVs
- Below the glass (centre), a test sample (white) is visible



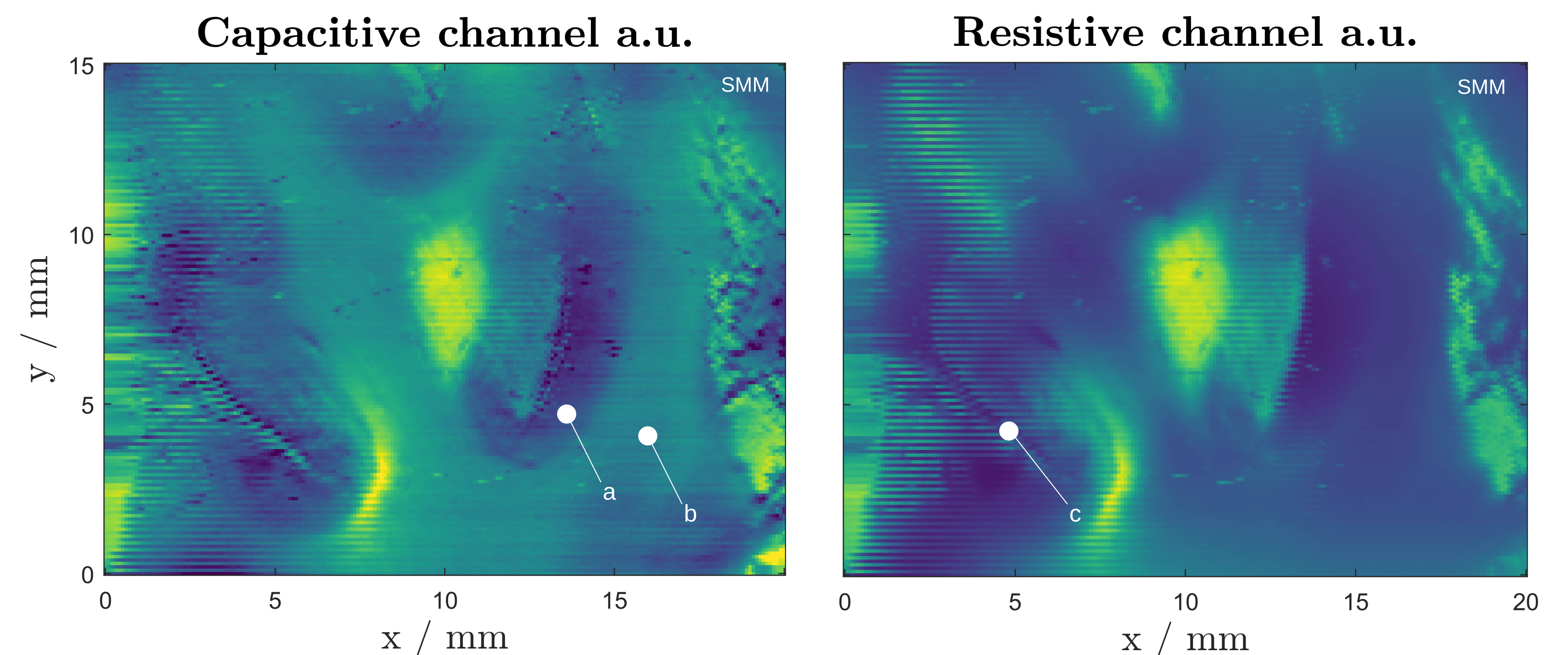
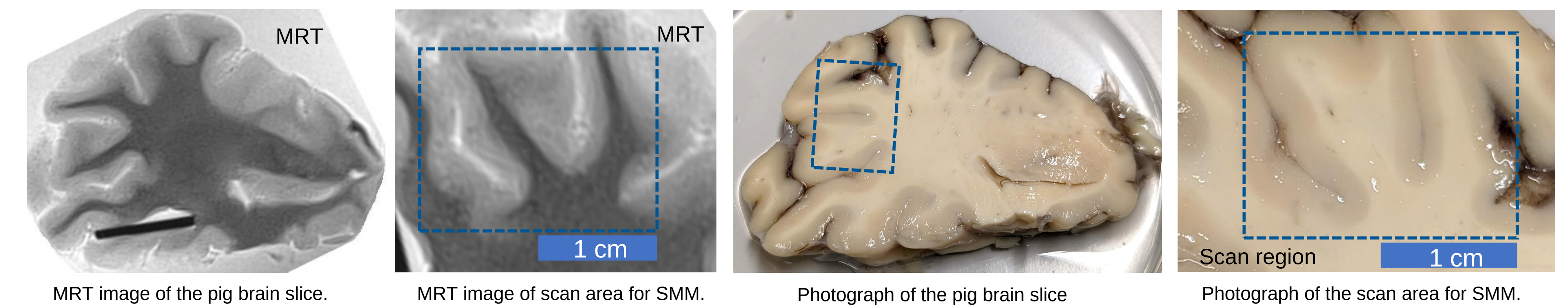
References

- F. Kazemi, F. Mohanna, and J. Ahmadi-Shokouh, "Detection of biological abnormalities using a near-field microwave microscope," *International Journal of Microwave and Wireless Technologies*, vol. 10, no. 8, pp. 933–941, 2018. doi:10.1017/S1759078718000752
- R. Schiavoni, G. Maletta, E. Filieri, A. Masciullo and A. Cataldo, "Microwave Reflectometry Sensing System for Low-Cost in-vivo Skin Cancer Diagnostics," in *IEEE Access*, vol. 11, pp. 13918–13928, 2023, doi: 10.1109
- S. A. R. Naqvi, A. Toaha Mobashsher, B. Mohammed, D. Foong and A. Abbosh, "Handheld Microwave System for In Vivo Skin Cancer Detection: Development and Clinical Validation," in *IEEE Transactions on Instrumentation and Measurement*, vol. 73, pp. 1–16, 2024, Art no. 6006816, doi: 10.1109/TIM.2024.3398123
- C. Origlia, D.O. Rodriguez-Duarte, J.A. Tobon Vazquez, J.-C. Bolomey, F. Vipiana, "Review of Microwave Near-Field Sensing and Imaging Devices in Medical Applications," in *Sensors* vol. 14, no. 4515, 2024, doi: 10.3390/s24144515
- Patent registration PCT/EP2023/064057

Measuring Electrical Properties of Biological Tissue

These measurements of a **fixed pig brain slice** demonstrate the system's applicability to the **biomedical** sector and showcases the measurement capability for the detection of abnormalities in biological tissue.

The frequency was fixed at 5.45 GHz and one probe was used. The scan region is 2 cm x 1.5 cm at a resolution of 0.1 mm.



A **capacitive** and a **resistive map** of a section of the brain slice are shown. **Gray matter** (a) and **white matter** (b) can be easily distinguished. **Sulci** (c) and their direction of growth are also visible due to the penetrating character of the microwave field.

Conclusion

- The scan head requires **minimal sample preparation** and is **physically** as well as **chemically robust**.
- Good electrical contrast allows to easily **distinguish different types of tissue**.
- Use cases: in-vivo/ex-vivo examination during **brain surgery**, in-vivo **skin cancer** detection.

Outlook

- Transmission measurements using multiple electrodes.
- Comparison with other techniques such as polarized diffuse backscattering.
- Clinical studies.
- Development of handheld device.

