

Quantum magnetometry

Highly sensitive testing of ferromagnetic materials

Early damage and stress detection

A flux guide, mounted on an optically pumped magnetometer (OPM), enables high-resolution measurements of the local magnetization of materials in the range of a few pT/mm².

Quantum sensors, such as optically pumped magnetometers (OPM), open up new possibilities in measurement technology. In a similar way to atomic clocks, they use atomic constants, meaning they do not need to be calibrated. Quantum mechanical principles such as entanglement improve the statistical measurement uncertainty compared with traditional approaches, so that the resulting sensors are robust, highly sensitive and have an extraordinary dynamic range.

Inside microfabricated optically pumped magnetometers (OPM), a laser uses the Larmor precession to measure the magnetic field in about 1 mm³ rubidium gas. This level of sensitivity is sufficient to detect damage due to material fatigue in a sample volume of just 0.1 mm³ based on its magnetization.

Fraunhofer IPM and Fraunhofer IWM work with additional partners on the development of novel, magnetic measurement systems for materials testing. The extreme sensitivity of OPM – just one millionth of the earth's magnetic field – enables the high-resolution magnetic detection of damage in ferromagnetic materials, such as the stress

concentration on imperfect welding connections in steel.

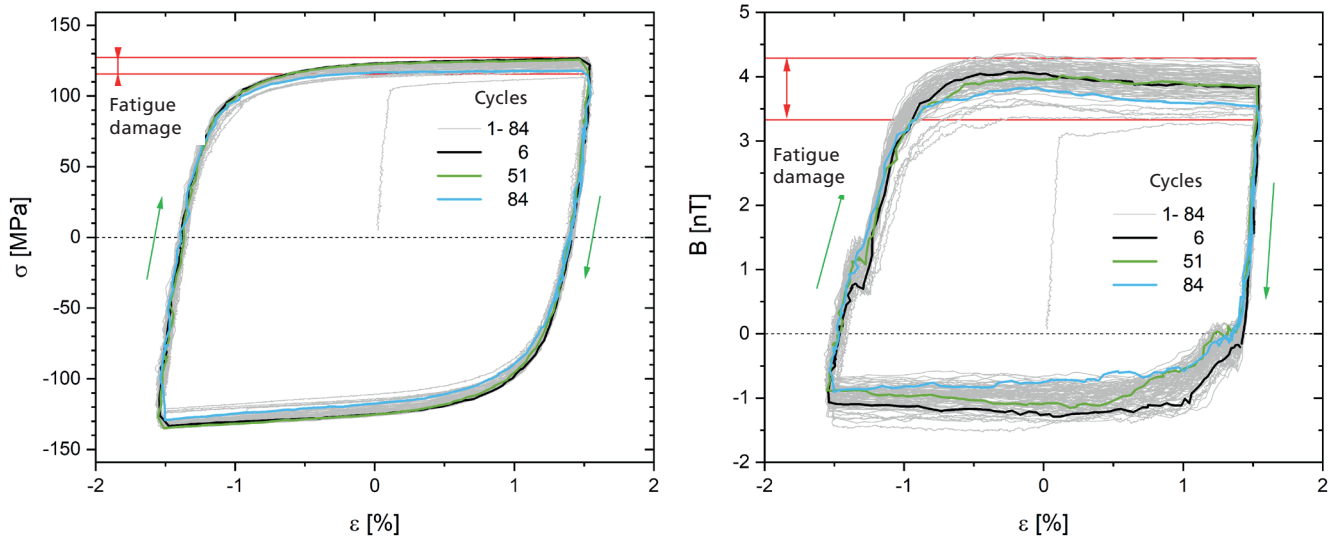
To enable industrial applications to benefit from this level of sensitivity, our team is working on new components such as flux guides as "magnetic prisms" for controlling sensitivity and spatial resolution, suitable actuators and a special shield against interfering magnetic fields from the surrounding area. Critical components can thus be tested to the strictest specifications in terms of functional safety at an early stage of production, even though the ambient conditions are anything but ideal for OPM in this context.

QMAG Quantum magnetometry

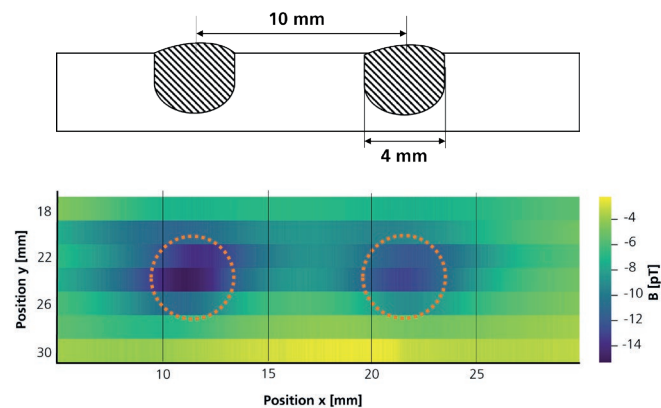
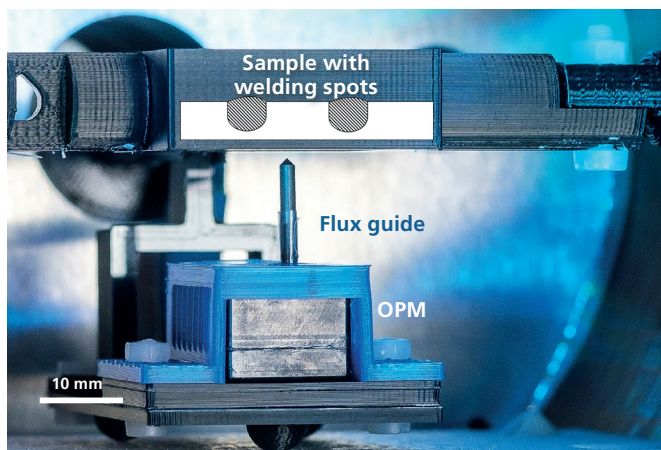
In the lighthouse project QMAG, six Fraunhofer institutes are cooperating in the fields of microelectronics, material testing and flow metering to develop industrial applications based on quantum magnetometers such as OPM or NV centers.

The project is funded in equal parts by the State of Baden-Württemberg and the Fraunhofer-Gesellschaft.

www.qmag.fraunhofer.de/en



Stress-strain diagram (left) and magnetic stray field variation B (right) of a ferritic steel in a strain-controlled fatigue trial. The magnetic stray field varies with both, stress σ (green arrows) and fatigue damage (red arrows).



The stress concentrations induced by welding spots on the top side alter the magnetic stray field B by a few pT – less than one milli-
oneth of the earth's magnetic field. As a result, the welding spots
become clearly visible in a 2D scan at the bottom of the sample.

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