Fraunhofer IPM

Quantum magnetometric camera

For highly sensitive and non-destructive material testing

Ronja Rasser, Peter Koss, and Jeremias Gutekunst (left to right) are developing a magnetic field camera to detect early-stage micro-defects in materials.

Over time, tiny hidden defects in materials can develop into cracks, jeopardizing the function and safety of technical equipment and systems. To detect such defects during production and improve quality assurance, we are developing a highly sensitive magnetic field camera. This camera measures the magnetic field strength of components using imaging and could be used in a production environment in the future.

High sensitivity through optically pumped atoms

Component defects often originate in minimal damage that occurs during production. In ferromagnetic materials, inhomogeneities in the magnetic field strength indicate hidden microcracks. These magnetic signals are in the range of a few picotesla. Today's methods of non-destructive material testing are largely based on magnetic stray fields. The established inspection methods include magnetic particle inspection and measurements using various types of magnetometers. However, these measurement methods only achieve limited spatial resolution and sensitivity or are time-consuming. In the development of the magnetic field camera, Fraunhofer IPM relies on the principle of optical pumping of alkali vapors. Thanks to this technology, the camera has the potential to achieve significantly higher sensitivity, spatial resolution and measurement speed than existing technologies.

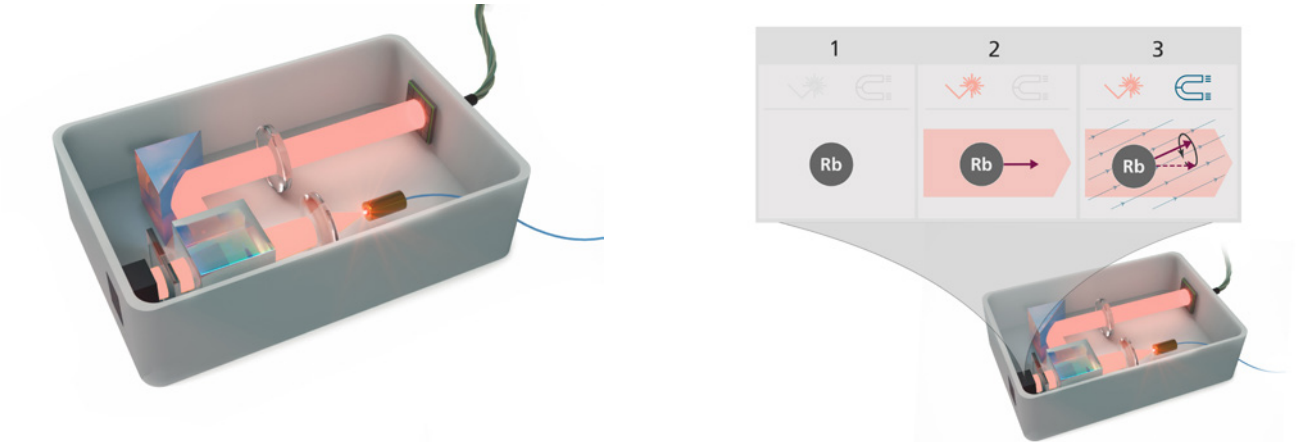
Two measuring principles

The magnetic field camera developed at Fraunhofer IPM uses two different physical principles to perform highly sensitive magnetic measurements: free spin precession (FSP) and zero-field resonances (also known as Hanle resonances). Both principles complement each other and enable comprehensive and precise recording of magnetic field strengths.

Cooperation
with Fraunhofer IPM

We see great potential in industrial quantum sensors and are open to ideas and collaborations in this emerging field of research.

Please feel free to contact us!



Schematic representation and measuring principle of a magnetic field camera.

Free Spin Precession (FSP)
FSP uses a vapor of alkali atoms, typically rubidium, in a buffer-gas cell. These atoms are optically pumped with a circularly polarized laser beam, aligning their spins in a preferred direction. Once the optical pumping is interrupted, the spins begin to precess in the presence of an external magnetic field. This precession occurs at a frequency that is proportional to the magnetic field strength – the so-called Larmor frequency.

Zero-field resonances (Hanle resonances)
In the case of the zero-field resonances, the change in the absorption of the optically pumped atomic vapor is examined when a perpendicular magnetic field is applied and varied. If the applied magnetic field goes through zero, a maximum change in the transmission of light is observed.

Quantum sensors for industry

Fraunhofer IPM is pursuing a number of different approaches to utilizing quantum sensors for industrial applications. We have built up research expertise in numerous projects, particularly in the field of optically pumped magnetometers (OPM). At the institute, we have the infrastructure and know-how to control the magnetic environment for our measurement systems very precisely. This includes a magnetically shielded room (MSR), in which we can carry out quantum sensing measurements in an optimal environment and in a large volume.

The institute has already developed a first quantum magnetometric system for flow measurement. For materials testing, a Fraunhofer team developed an optically pumped magnetometer that detects damage such as stress concentrations in welds. Together with the Intelligent Machine-Brain Interfacing Technology (IMBIT) research center, Fraunhofer IPM is also working with highly sensitive OPM-based quantum sensors for magnetoencephalography (MEG).

Technical specifications

Parameter	Camera concept 1*	Camera concept 2**
Measurement method	Free Spin Precession (FSP)	Zero-field resonance
Measurabel magnetic field strength	µT range	Sub-nT range
Spatial resolution	approx. 100 micrometer	approx. 100 micrometer
Active measurement surface	5 mm × 5 mm	5 mm × 5 mm

* The FSP approach is being funded by the BMBF as part of the QuMa2 project (high-resolution quantum magnetometric camera for fast inline material testing).
** The zero-field resonance approach is beging developed in a project funded by the Fraunhofer-Gesellschaft.

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