MOBILITY & PRODUCTION

Fields of Expertise TU Graz

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Peter Fischer,
Mobility & Production
Source: Lunghammer – TU Graz

According to information from the Copernicus climate change service, April 2024 was the 11th consecutive month where the global average temperature was higher than in the respective month of the year before.

Where will this lead?

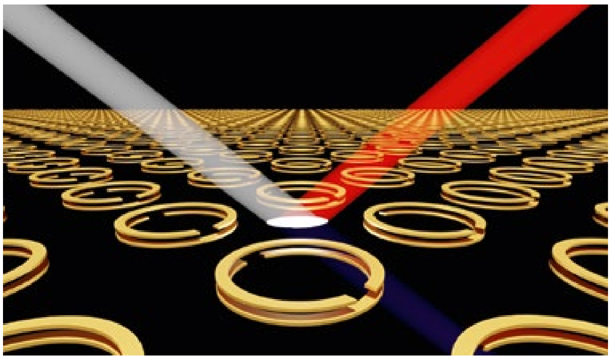
CO_2 is a global problem. Solving the problem requires global thinking. Around 80% of the energy consumed worldwide is still fossil energy. Europe is slightly better, but not much. Globally, CO_2 emissions from the transport sector account for around 25% of total emissions and are still rising substantially. This is also true for Europe, while CO_2 emissions in other sectors such as industry, households and energy production are decreasing.

This should actually make it clear that ACTION is urgently needed now, instead of passing the buck back and forth with doubts about all the possible replacement technologies.

1) Save energy and keep saving it
2) Generate renewable energy and generate more of it
3) Use this energy as efficiently as possible
4) The sector with the greatest need to change is the transport sector
5) What is the best technological path to follow in mobility? The most efficient drive technology is direct or battery electric drive.

This change has to take place as quickly as possible, but it will not happen overnight. Until then, it is important to use existing technologies as efficiently as possible. This includes combustion engines and biological fuels and to develop them towards higher efficiencies and to support electric drives. This will not solve the global CO_2 problem, but it is an important path to follow.

And WHEN? As soon as possible. And HOW? Certainly not with a 2.5-ton SUV.



Reinhard Klambauer and Alexander Bergmann

Structured Matter-Based Sensing for Next Generation Powertrains

As the powertrains and electromobility sector continue to advance at a rapid pace, the need for innovative sensor technologies becomes increasingly crucial.

Sensors, which are instrumental in monitoring, controlling, and optimizing various aspects of powertrain systems and electric vehicles (EVs), are key to enhancing performance, efficiency, and safety. Our research embedded in the Christan Doppler Laboratory for Structured Matter-Based Sensing in cooperation with Peter Banzer from the University Graz focuses on sensor technologies based on structured matter, specifically tailored for powertrain and electric vehicle applications with telemetric functionality. From traditional internal combustion engines to cutting-edge electric propulsion systems, the integration of advanced sensors holds the potential to transform the automotive industry, paving the way for the development of more efficient, reliable, safe, and sustainable mobility solutions.

STRUCTURED MATTER – STRUCTURED LIGHT – SCIENTIFIC CHALLENGES

The fields of structured matter and structured light represent two fascinating branches of modern optics that have developed in parallel and yet independently of each other until recently. The former deals with the propagation of linearly or circularly polarized light in complex materials with properties that do not occur in nature. >

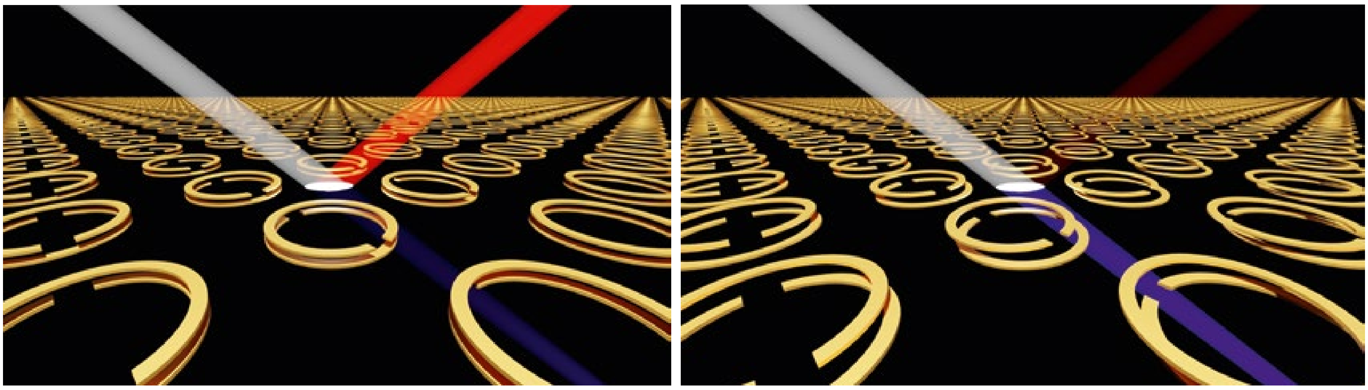


Figure 1: Depiction of the change of transmission of an electromagnetic wave depending on the geometric structure of an artificial material.
Source: Reinhard Klambauer

The latter concerns the propagation of Gaussian beams in such materials. However, light can also be a more complex phenomenon. In addition to the conventional polarization states, light rays can also be radially or azimuthally polarized and carry an orbital angular momentum (OAM). Structured light beams containing phase or polarization singularities enable properties and applications such as diffraction-free propagation, single-molecule spectroscopy, nanoscale focusing and even particle acceleration. Metamaterials permit unprecedented control of light propagation. Metamaterials open up new possibilities for the utilization of spin and quantum optical phenomena and enable new linear and nonlinear optical properties and functions. Provided that metamaterials can be engineered to exhibit almost any optical property imaginable, they are expected to alter the light-matter interactions of structured light.

Structured light can also contribute to the development of complex metamaterial structures. Potential applications include nanoscale imaging, optically active metamaterial surfaces and sensor applications ranging from mechanical to chemical quantities. The scientific and technological challenges lie in the feasibility and realizability of the sheer endless possibilities.

WHAT IS OUR RESEARCH ABOUT? – RESEARCH QUESTIONS

- Can non-local or non-linear effects in structured matter (e.g. negative refractive index, ENZ, induced magnetism) be used to design sensor effects that go beyond classical material physics?
- Which additional degrees of freedom can be utilized by spatially structured interaction of matter and electromagnetic waves (e.g. generating artificial magnetic response in non-magnetic materials, chirality, rotational Doppler effect)?
- What are bi-isotropic materials' physical limits and possibilities (e.g., coupling of electric and magnetic fields, linear and non-linear, novel field manipulations)?
- What are bi-anisotropic materials' physical limits and possibilities (e.g., polarization as an additional degree of freedom in the coupling between electric and magnetic fields, spatial degrees of freedom, OAM)?
- Where are the limits in the design of artificial piezoelectric/piezomagnetic / magneto-strictive materials from a material point of view?

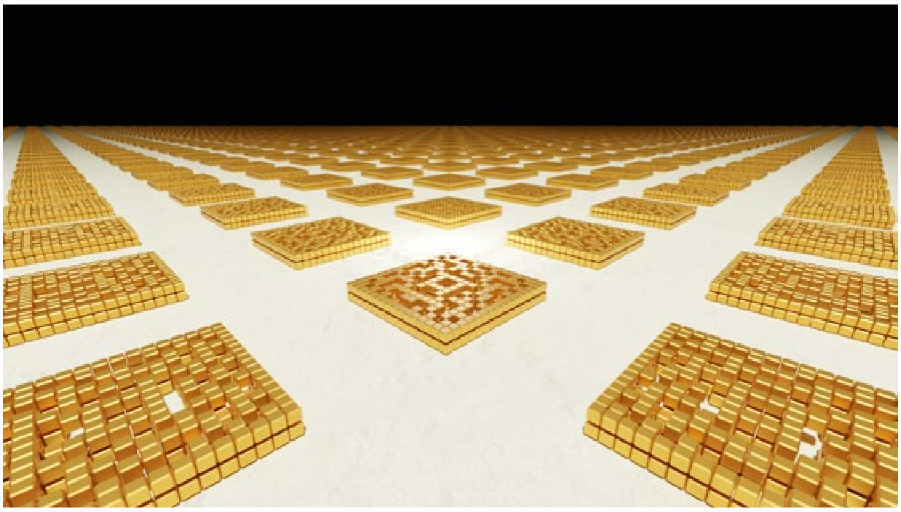
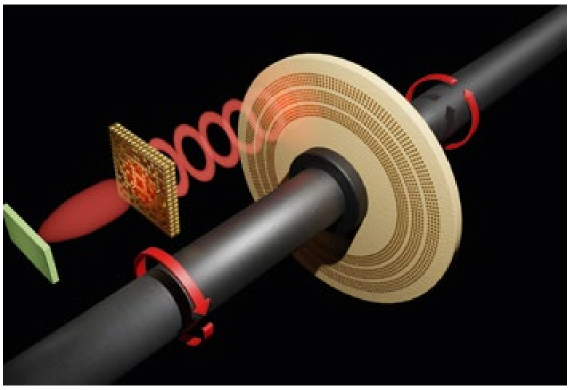


Figure 2: Schematic depiction of a metamaterial tailored to influence incoming electromagnetic waves in certain ways, such as acting on the polarisation state.
Source: Reinhard Klambauer



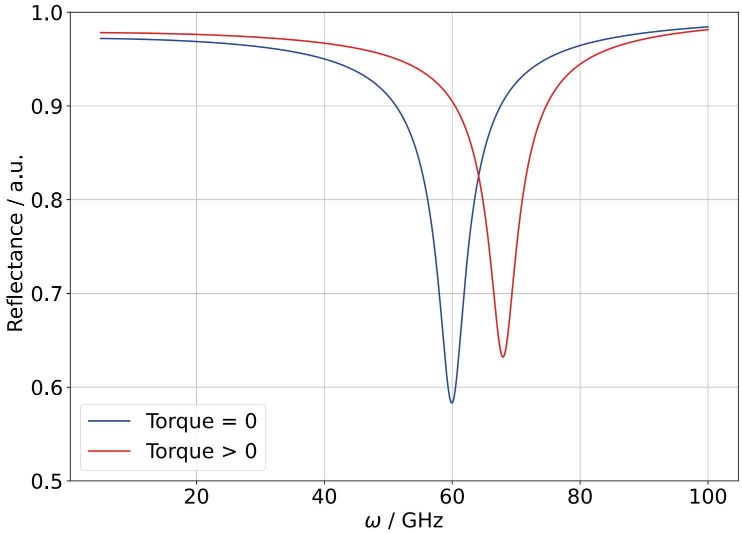


Figure 3: Telemetric single target torque/temperature/speed measurement with mm-waves, based on complex materials and complex light.

Source: Reinhard Klambauer, right: Alexander Schossmann

EXPECTED RESULTS – APPLICATIONS FOR NEXT GENERATION POWERTRAINS

In the foreseeable future, optical metasurfaces will open up new possibilities for developing beam shaping and guidance, plasmonic lenses and other ultra-thin components for "optics on a chip". In combination with structured light, new components for PiCs and photonic systems for refractive index/sonic field measurement will be developed.

One of the investigated sensor effects has an application in next generation powertrains. In order to control the driving behaviour of modern electrical vehicles in every situation, engine control units are performing complex control algorithms which rely on dependable results of a wide variety of different automotive sensors. One crucial parameter is the applied torque on the wheels of the vehicle. Although this is a key parameter for controlling the car, at the moment there is no viable cost-effective solution for a direct measurement. The latest engine control units employ an estimation methodology based on ABS sensor data and the torque output of the driving electrical motor, which is determined via the measurement of voltage, current and rotary position. A direct measurement of the torque allows for a more accurate assessment of the current driving situation, which can be crucial for the vehicle's safety, performance and efficiency. To enable such a sensor system with minimal impact on the vehicle's construction, bespoke resonant metamaterial structures are employed to detect spatial shifts in the range of μm caused by the torsion of drive shafts. These spatial shifts are converted into a frequency shift, which can be cost-effectively detected by commercial radar chips (see Figure 3).

Alexander Bergmann (left) is head of the Institute for Electrical Measurement and Sensor Systems and leads the CD lab for structured matter-based sensing in cooperation with Peter Banzer.

One of the key researchers in this laboratory is Reinhard Klambauer. He has been working in the field of sensor systems since 2014 with a focus on the application of novel ultrasonic sensing principles for flow measurement and batterie cell characterisation. In his current position as senior scientist and part of the CD lab for structured matter-based sensing, he is currently working on the application of sensor systems based on electromagnetic waves in the mm wavelength regime.

Sources: Oliver Wolf