INTEGRATED
ENGINEERING SOFTWARE

30 YEARS
OPTIMIZING DESIGNS

Analyzing Faraday isolators in sophisticated optical systems

Qioptiq is a global manufacturer of sophisticated optical systems. The company is a pioneer in the field of photonics - one of the central growth markets of the 21st century. Its core business includes the development and production of customer-specific sub-systems and integrated system solutions which meet stringent technological demands. The company's product range focuses on Information Technology & Communications, Health Care & Life Sciences and Industrial Manufacturing markets.

Kristiane Gans, an engineer in research and development at Qioptiq's BU Laser Technology, is based in Munich where the company uses INTEGRATED Engineering Software when modeling its designs. "Qioptiq has been using AMPERES for seven years, though I have only been working with it for the past four since I transferred to doing this research."

AMPERES is an easy-to-use 3D magnetic field solver for applications such as clutches, solenoids, sensors, actuators, MRI and magnetic shielding. Fast and accurate, it can calculate force, torque, flux linkage and inductance. Its powerful parametric solvers allow designers to automatically vary and experiment with geometry, materials and sources, reducing the tedious and repetitive task of fine–tuning multiple design parameters.

Gans is working on Faraday isolaters that are situated at the front of lasers. These ensure that the reflection back off the surface of elements in the optical path do not confuse the laser itself. "Our customers are mainly producers that use our products to develop lasers which cover a wide range of uses from medical to visual.

Faraday isolators are optical components which allow light to travel in only one direction and the mode of operation is based on the non-linear Faraday effect (magneto rotation). In principle, the function of an optical isolator is analogous to that of an electrical diode. The isolators are composed of three elements; the entrance polarizer, the faraday rotator and the exit polarizer.

Thin film polarizers are commonly used as entrance and exit polarizers, typically in form of a special polarizing beam splitter cube, and have an extremely high extinction ratio. Designed for use with high power lasers, the key element of the Faraday isolator is the Faraday rotator which consists of a strong permanent magnet containing a crystal with a high Verdet constant.

Light of any polarization entering the entrance polarizer exits as horizontally or vertically linearly polarized light. Since laser light is usually linearly polarized, one can match the orientation of the entrance polarizer and the laser by simply rotating the isolator. Light then passes through the Faraday rotator. For most wavelengths the crystal is a Terbium Gallium Garnet (TGG) crystal which is placed in a strong homogeneous magnetic field. The crystal length and the magnetic field strength are adjusted so that the light polarization is rotated by 45° on exiting the crystal.

If light of any polarization, but with a reversed direction of propagation, meets the exit polarizer, it leaves at +45°, passes through the Faraday rotator and is again rotated by +45°. The non-reciprocal nature of the Faraday effect results in the direction of rotation once again being counter clockwise as viewed in the north/south direction of the magnetic field.

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Upon leaving the Faraday rotator, the polarization has gone through two +45° rotations resulting in a total rotation of +90°. In this polarization the direction the light is deflected laterally by the entrance polarizer.

The maximum isolation of the Faraday isolator is limited by the inhomogenities of the TGG crystal and the magnetic field. However, it is possible to square the extinction ratio by placing two isolators in series and by arranging the polarity of the two magnets to be opposite to each other. This way the polarization direction of the transmitted light remains unchanged in the transmission direction and the effect of both magnetic fields is enhanced, which leads to a more compact isolator. The strength of this effect depends on the distance between the two magnets and can be used to tune the isolator to different wavelengths. The adjustment is necessary because the rotational angle of the TGG crystal is wavelength and temperature dependent.

"This is what we have been developing at BU Laser Technology since the early 1990s," continues Gans. "Before we started to use AMPERES it was just a case of trial and error but since we have had the software we are able to calculate the mechanistic skills of the components. We only work with cylindrical magnets so the laser beam is always inside the magnetic field. We need to know just how strong the magnetic field is at any given point and it is very interesting to see what will really happen. The magnetic field is not homogeneous, it is different at different places, and we need to have this information.

"Working with AMPERES has lead to a more straight-forward product development process because it is no longer based on guesswork. We now know in advance what we can expect at the end. We can change the parameters of the geometry and can see straight away the effect that we will get by changing for example the diameter or length. I often use the parametric mode to analyze trends in the design."

Gans has been on a visit to the INTEGRATED Engineering Software workshop in Winnipeg. "It was really great and I found it so useful. The visit helped me to better understand the software and learn about some of its capabilities that I was not aware of prior to the visit. One thing that I learnt about was the parametric run which now plays a very important role in the processes I use," adds Gans. "Another thing they taught me was how to import a model from CAD. It was really good to know that you can import all the stuff that you constructed in CAD so that you don't have to do it again. It is very easy to have the 3D model and import it into the AMPERES software."

"I also found that having got to know the people in the Winnipeg workshop I now feel that I can ask them questions about whatever I am working on. This division is the only section of our company using the AMPERES software so there is no one else that I can ask about it. This means that the support I get from INTEGRATED is very important to me and it is also very good," concludes Gans.