Thick holograms may replace spatial filters

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he demise of the ubiquitous lens-and-pinhole spatial filter may result from a collaboration between researchers from the Vavilov State Optical Institute (VSOI) of the Ioffe Physical Technical Institute and Machinery Sciences Institute (St. Petersburg, Russia), Northeast Photosciences (Hollis, NH), and the Massachusetts Institute of Technology (MIT, Cambridge, MA). Recorded in a new holographic medium, the novel filter has an angular selectivity of 10-3 to 10-4 radians and, according to VSOI researcher Irina Semenova, should eventually have a diffraction efficiency of around 50%.

Apart from being hard to align correctly, ordinary spatial filters are both expensive and difficult to use with high-power lasers. After focusing, the intensity of the light can be so high that the beam burns right through the pinhole substrate. With the holographic approach, however, focusing is not required, so this problem can be avoided. The alignment is significantly easier because only the angle of the incoming beam is important, not the position. With conventional spatial filters, both issues are critical.

A very simple idea--Bragg selectivity--is the basis of the new technique developed by Northeast Photosciences. Basically, the thicker a hologram is, the more selective it is about the angle of its reconstruction light. So, diverging rays are weeded out if they are incident from outside of the angular tolerance of the hologram. If this is done with two perpendicular holograms, then the beam is fully filtered.

The trick is in making holograms that are thick enough to really clean the beam. Conventional holographic emulsions are usually measured in tens or perhaps a few hundreds of microns. For this so-called "nonspatial" filtering, on the other hand, the hologram has to be 0.5-2 mm thick.

New materials

At the VSOI, scientists have been working with new materials that can meet this requirement. One medium is a silicate glass matrix riddled with thin (10-30 nm) internal connecting pores. If the pores are coated with a photosensitive material, then the structure acts as a very thick, rigid holographic medium. If chemical processing is necessary, then the pores can also act as capillaries to bring developer and other solutions to the emulsion.

Another holographic material combines poly(methylmethacrylate), or PMMA, with photochromic quinone molecules. On exposure, two things occur: phenanthrenic structures associated with polymers are formed, creating one hologram, and concentrations of free quinone are built up, creating another. Until postprocessing, these two gratings cancel each other out. After heat treatment, however, the quinone molecules are evenly redistributed, leaving a single, efficient hologram.

Ioffe Institute researchers Irina Semenova and Nadya Reinhand have been on-site at Northeast Photosciences this year working on a one-dimensional (1-D) version of the filter using Russian-recorded holograms. The work was funded by the European Office of Aerospace Research and Development, which was developed to encourage Russian collaboration with commercial concerns in the USA. Along with MIT`s Selim Shahriar and Northeast Photoscience`s Jacques Ludman and Juanita Riccobono, they succeeded in building a prototype, demonstrated in July at the SPIE annual meeting in San Diego, CA.1

According to Semenova, the efficiency of the 1-D filter is 70% or less. With losses, this would produce a 2-D filter that is only about 30% efficient. However, she says, holograms with 80% diffraction efficiency have been recorded in Russia. By optimizing the holographic processes and the recording, she says, the two-hologram system should diffract 50% of the incoming beam.

Northeast Photosciences has just been awarded a Phase II Small Business Technology Transfer grant of $500,000 from the Ballistic Missile Defense Organization. According to the company`s president Jacques Ludman, this funding should enable building a complete 2-D filter within months. Within a year, he hopes to see an initial model of the filter available commercially.

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