SINGLE-PULSE "LIGHT IN FLIGHT" HOLOGRAPHY

Ed Wesly

Fifteen years ago Nils Abramson conceived the "Light in Flight" method of recording as a way of studying the behavior of a single wavefront of light.[1] Ten years ago the first successful experiments were accomplished, even though he had no pulsed laser with which to generate the proper size short pulses. (Capturing a slice of light a few picoseconds in duration, which is a few millimeters long, would be nice.) He cleverly took the etalon out of a continuous wave argon laser at the Royal Institute of Technology in Stockholm, Sweden, to generate wavefronts coherent for only a few centimeters. These wavefronts starred in his first Light in Flight holographic movie, "Reflections from a Mirror." Five years later he gained access to a mode-locked dye laser at Spectra-Physics, which emitted extremely short pulses. But a single pulse did not have enough energy to expose a holographic plate, so he had to use a train of them to make recordings of light passing through lenses and optical fibers.

Now, finally, Abramson has had the chance to silence his critics and use just a single pulse in experiments conducted in October 1987 at Northwestern University in Evanston, Illinois. A frequency-doubled mode-locked Nd:YAG laser ($\lambda = 533$ nanometers) from the lab of Dr. Ken Spears of the chemistry department was used as the photon source. Although other, similar lasers are capable of emitting twenty-five picosecond (and shorter) pulses, none of them has the eight millijoules of energy that this one has, thanks to its many stages of amplification. This is enough light in a single pulse for Abramson's experiments. (Eight millijoules from a YAG laser may not sound like much compared with eight full joules from a ruby laser, but the peak powers are the same when you consider that twenty-five picoseconds are 1/1,000 of twenty-five nanoseconds, and there are one thousand millijoules in a joule.) Light from this laser enters Abramson's lab through a hole in the wall, and then he works his magic with it. He does all the setup work himself, using a fluorescent screen instead of burn paper to show him where the beam is for alignment purposes. With the amount of peak energy available—three hundred megawatts—the screen glows for about half an hour after getting hit with the YAG, and it seems to darken where the HeNe alignment laser meets it. Unfortunately, this technique doesn't work with a ruby laser, since the fluorescence is always at a longer wavelength than the original input, making it invisible in the infrared. Abramson also measures the path lengths with string to equalize them to within 7.5 millimeters (the distance that light travels in twenty-five picoseconds), and he even develops the Agfa 10E56 plates himself in a special developer designed for ultrashort exposures.

He began his experiments by making two-beam gratings to see the exact physical dimensions of the pulse. To do this, he measured the width of the area on the plate that diffracted the light. Then he repeated the mirror experiment of ten years ago as a control.

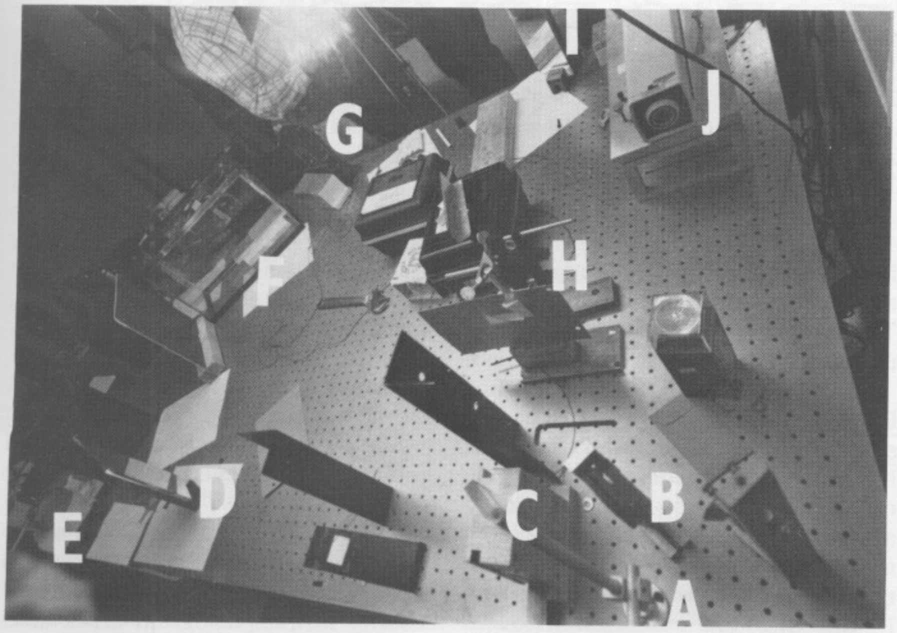
His newest endeavors were designed to test the feasibility of using Light in Flight techniques in medicine. Light certainly can pass through living tissue, as evidenced by putting the business end of a flashlight in the palm of your hand and witnessing the diffuse red glow on the back of your hand. Abramson thinks that if the "first light" leaving the hand (which is the light that travels most directly and is least scattered) were recorded using Light in Flight techniques, then a picture of what's inside could be made.

His next experiment used the object shown in Fig. 1 to simulate body parts. Two different thicknesses of plexiglas were sandwiched between two diffusing plates. Light from behind scatters through the first diffuser, and some heads directly for the second diffuser while other parts of the original beam are delayed going through the different thicknesses of plexiglas. The light leaving the sandwich will only interfere with the reference beam when both beams arrive simultaneously at the "holoplate." Since the reference beam travels horizontally across the plate at such an oblique angle as to be

Three views of Light in Flight hologram

Left: Light issuing through diffusing glass.
Middle: Light delayed five picoseconds by thin glass block.
Right: Light emerging last through double plexiglas thickness.

Photographs by Hans Bjelkhagen



Setup for single-pulse Light in Flight recording at Northwestern University. The beam from the Nd:YAG laser comes out of the pipe at A, is turned 90° by a steering mirror at B, and is split in two by a glass block at C, with the transmitted light being expanded by lenses at D and steered by mirror E through the aquarium tank at F, where the backlit objects are placed. The object light travels on to the holographic plate holder at G. The weak reflection from the beamsplitter is expanded by lenses at H and guided to the plate holder by mirror I. The beam from a 5mW HeNe laser is used for alignment and joins the YAG beam by sneaking in from behind the dielectric mirror at B.

almost parallel to it, the left side of the hologram will record the first light issuing from the object, and the right side, the light that has been delayed. Looking at this hologram with only one eye (not two, since they will each see the recording of different times and then get confused), sweeping from left to right, one sees first the entire ground glass except for the shadow caused by the two blocks inside the sandwich. Farther right one sees a bright area in the center of the object, which is the light delayed by the thin plexiglas block and therefore recorded later. Finally, at the extreme right, there is a bright spot representing the light that had been delayed the most by the thicker block. (See the suite of photographs above.) Abramson also holographed slices of potatoes, which emulate the translucency of flesh. He also tried contouring experiments, and in one similar to his famous propeller hologram he used a *running* ventilation fan—with a twenty-five picosecond pulse, the tolerance for movement goes up to a velocity of three kilometers per second![2]

Abramson plans to pursue this type of research in the future, since there is much interest in this field by the agency that supplied the grant, the Midwest Biomedical Laser Institute. The goal is to see through the hand, and Abramson needs more energy in shorter pulses to do that. ("The bigger they are, the easier they are to work with," he says.) Perhaps a free electron laser could be used for this more humanitarian purpose; it has been much maligned for its association with the Strategic Defense Initiative. Who knows, in the future Light in Flight holograms might replace those nasty X rays at the local hospital, thanks to the genius of Nils Abramson.

Notes

[1] Originally he called it "Lightwave Surfing" since he has an affinity for windsurfing. The early experiments are chronicled in his book, *The Making and Evaluation of Holograms,* Academic Press, 1981, as well as in *Holosphere,* vol. 10, no. 2, p. 1 and in the Proceedings of SPIE, *Recent Advances in Holography,* vol. 215, p. 140.

[2] The propeller experiment is outlined in *The Making and Evaluation of Holograms.* For more recent work see Abramson's article "Optical Fiber Tested Using Light in Flight Recording by Holography," in *Applied Optics* (October 1987), p. 4657.

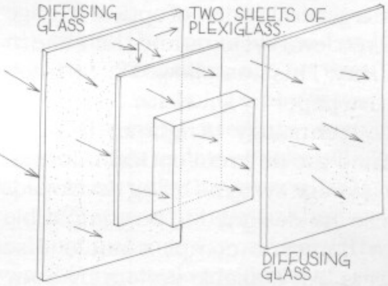
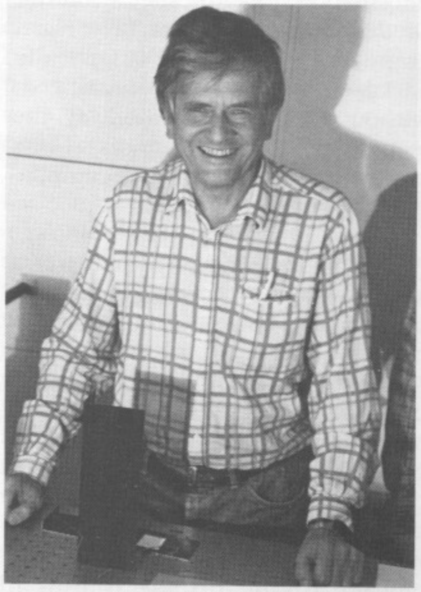


Fig. 1 Exploded view of object used to simulate internal structure of human body

Illustration by Lynn Schultz



Nils Abramson in lab at Northwestern University

Photograph by Ed Wesly