stars has been analyzed interferometrically. The lens was cracked by accident when Galileo was still alive, and was later donated to the Grand Duke of Tuscany, who placed it in an ivory frame in 1677. The lens is 58 mm in diameter, with a useful aperture of 38 mm; the focal length is 1.7 m. A double-pass Fizeau interferogram at the wavelength of 633 nm is shown in the figure below. The main fringe discontinuity results from a residual mismatch of the fragments. Other irregularities are due to the poor quality of the glass. Although in the presence of these anomalies, it appears that at a single wavelength the lens is nearly diffraction limited, the actual performance being degraded only by chromatic aberration.

This surprising result sheds light on the development of early optical engineering, and on Galileo's efforts in optical testing. The lenses available during Galileo's lifetime were intended for use by spectacle-makers and for the loose tolerances of the eye. In the absence of fabrication techniques that could guarantee optical quality, Galileo purchased great quantities of lenses, and then chose the best performing ones. The selection process was quite severe: A letter relates that of some 300 lenses made, 22 were selected, but only three passed, and even these three were not deemed perfect.

In the documents that remain, no mention is made of the testing methods used by Galileo. There is no doubt, however, that the success of his telescopes was based largely on the superior quality of the optics.

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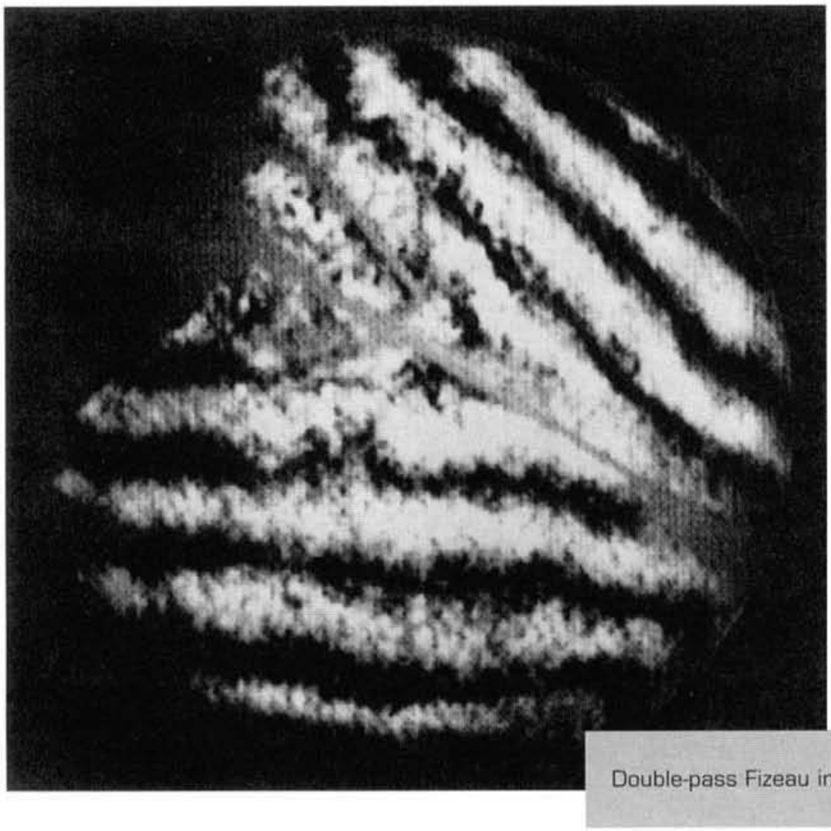

Double-pass Fizeau interferogram of Galileo's cracked lens.

Time-reversal Operator for the State of Polarization

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The concept of an Ortho-Conjugated Mirror (OCM), or Faraday Rotator Mirror, was first demonstrated in 1989[1] and has recently found application in the field of fiber optic circuits[1] and fiber optic current sensors.[2,3] The OCM polarizes the light and conveys the time-reversal properties displayed by the Phase Conjugated Mirror (PCM) for the optical phase.[5] Both devices effectively retrace optical paths, *i.e.*, circuits where light maintains a mirror symmetry, and both devices return the light in the opposite state, which means reverse propagation direction for the PCM and orthogonal state of polarization (SOP) for the OCM.

Consider a light beam propagating along a birefringent optical path. The beam's properties are described by the Jones matrix, *J*. When a mirror reflects the light along the same path, the returning SOP differs from the input SOP depending on the specific form of *J* and the effects of birefringence are not cancelled out. If the birefringence is perturbed, the returning light SOP changes in an unpredictable way, resulting in polarization noise found in many optical and fiber optic circuits. Since the discovery of the OCM properties, only post-processing methods permitted the control of the noise caused by birefringence fluctuations.

Imagine the OCM as a black box whose Jones matrix representation is $i\sigma_y$, the 'y' component of the Pauli matrix. When the OCM replaces the mirror any effect of the path birefringence on the returning beam disappears and the returning light polarization is maintained orthogonal to the input light. If you enter in the OCM retracing optical circuit via a polarizer, the returning light is completely blocked and it is not perturbed by the path birefringence modulations. On a Poincaré sphere representation of the SOP evolution, the OCM unwinds the path traced on the sphere surface during the first half propagation.[4-6]

An OCM can be created simply by placing a Faraday rotator in front of a common metallic mirror. The Faraday rotator must be tuned with rotation power at exactly 45°. Contrary to the PCM, the realisation of an effective OCM does not require the use of optical non-linear effect.

The properties of the OCM have analogies with time-reversal operators.[5,7] In fact, $i\sigma_y K$ is the quantum mechanical time-reversal operator for the spin, and the photon spin is behind the SOP property of the light.

Since its discovery, the OCM has been used in a number of optical applications. For example, polarization-insensitive interferometers in Michelson or ring configurations.[1] These optical circuits provide the basis for the development of coherent optical sensors like hydrophones, strain-gauges, thermometers, and fiber optic gyros. A generalization of the OCM properties for dicroic birefringent components, proposed by Bandhari,[7] has been successfully proved by van Deventer.[8] The results can be applied to the development polarization-independent optical amplifiers or lasers and to solve the optical-reflection sensitivity in many circuits. Another use is in current sensors based on the Faraday effect.[2,3] Unlike optical activity, the magneto-optical induced activity is non-reciprocal and cannot be compensated by the OCM. Nevertheless, the presence of the OCM limits the effects of vibrations and temperature changes on the fiber optic current circuits.

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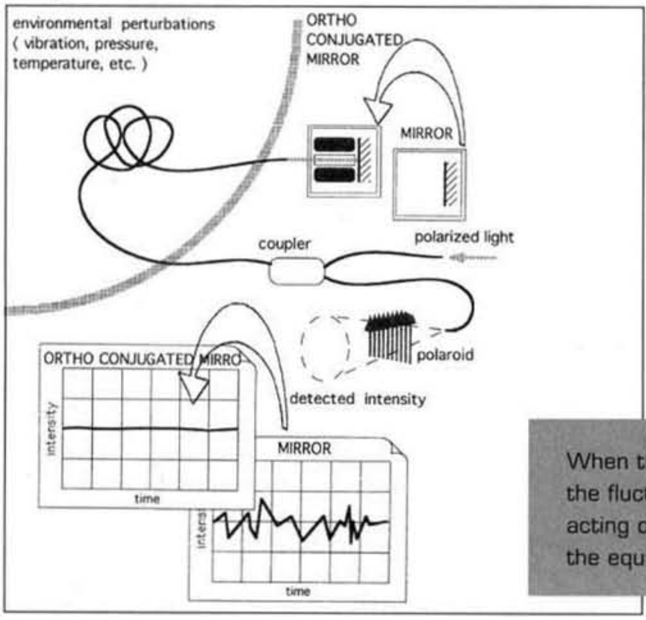

When the mirror is replaced by the Ortho Conjugated Mirror (OCM), the fluctuations of polarization induced by environmental perturbations acting on the optical fiber are completely cancelled. The OCM produces the equivalent of the time reversal operation for the polarization state.

Magnetorheological Finishing

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Magnetorheological (MR) suspensions, used in optical manufacturing, constitute a new and novel optical finishing technology. These suspensions consist of micron-sized magnetic particles in a carrier liquid[1] and are representative of a class of "intelligent" fluids, *i.e.* media with controllable properties. They can exhibit rapid and reversible changes in their structure. As an example, the rheological property of viscosity varies by over two orders of magnitude with the application of a magnetic field.[2] The ability to induce changes in mechanical properties has been used in a variety of actuators from vibration isolators and shock absorbers to robotic positioning devices by the Byelocorp Scientific staff,[3] and now to the figuring and finishing of optics.[4]

The method for optical finishing with a MR suspension is illustrated in the figure. The process starts with a glass lens that has been generated by deterministic microgrinding on an *Opticam* computer-controlled machining center at the Center for Optics Manufacturing (COM). A typical microground part has the correct surface figure within 1/2 wave p-v; surface roughness less than 150Å rms; and subsurface damage of less than 2 µm.[5] The generated part is mounted on a rotating spindle that is placed into contact with the MR suspension confined within a non-magnetic rotating trough. Conventional polishing abrasives are added to the suspension, and polishing occurs in the area affected by the electromagnet.

The MR finishing process is best understood by thinking of the MR suspension as a compliant replacement for the conventional rigid lap in the loose abrasive grinding or polishing process. Application of a magnetic field causes the viscosity and plasticity of the MR suspension to change from low (soft) to high (stiff). A zone of high pressure is created in a spot beneath the surface of the part. The rotating trough continuously delivers new polishing abrasive particles into the high pressure zone where, under the action of nonhomogeneous magnetic fields, they contact the glass surface to effect material removal. The magnitude and form of the zone's polishing spot are controlled by the magnetic field.

Polishing of a spherical surface is achieved by varying the lens contact angle, Θ, and the dwell time with computer