The Fabry-Perot Interferometer
Maurice Paul Auguste Charles Fabry (1867 – 1945)

When I had my house renovated a few years ago, our builder noticed something in the skylight. Smack in the centre of the triple-glazed pane was a set of gorgeous multicoloured rings. “Newton’s rings”, I said, as I made them to expand and contract by pressing my fingers against the pane. “Aren’t they beautiful?” He looked distinctly unimpressed; to him it was just a flaw.

Like the iridescent colours that appear in a pool of greasy water, films and gaps between transparent materials give rise to delicate colours. Because Newton was so strongly attached to the idea of light as corpuscules, his thoughts on the origin of the coloured fringes were quite vague; he muttered about alternating “fits of reflexion” and “fits of refraction”. It was not until the 1830s that George Biddell Airy, one of the great proponents of the wave theory of light, laid down the rigorous theory to describe the path of light passing between two parallel plates separated by a narrow gap. He predicted that there would be interference; his formula would form the basis of an exceptionally sensitive interferometer that has been in use for well over a century. It was developed by a man who was obsessed with astronomy as a boy.

Charles Fabry was born into a scientific family. His grandfather and his three older brothers all went into science or engineering, studying at the École Polytechnique in Paris. After graduating from there too, Fabry moved back to Marseille to study for a PhD with Jules Macé de Lepinay, France’s leading expert on optical fringes. It was customary in those days for new graduates to be sent to teach in technical colleges for a few months before taking up more permanent academic positions, and Fabry spent time in several cities across France, including Bordeaux. One of the teachers there, Raymond Boulouch (1861-1937), made an interesting observation while demonstrating Newton’s rings using a sodium lamp. He part-silvered two pieces of optically flat glass, placed them exactly parallel and and focused a beam of light onto one side. The transmitted light consisted of a series of concentric circular fringes. By adjusting the gap between the plates, the fringes resolved into pairs, the doublet splitting of the sodium D-line. Was the experiment inspired by conversations with Fabry, whose newly-written thesis focused on fringes?

Fabry meanwhile returned to Marseille, where he was appointed “maître de conferences” assigned to the teaching of physics to medical students. He was a brilliant and popular lecturer both to students and to the general public, invariably illustrating his points with demonstrations. In the obituary he wrote after Fabry’s death, Louis de Broglie regretted that Fabry had never been appointed to the Royal Institution.

In his research Fabry became interested in the accurate measurement of small distances; interferometry might provide a solution. He teamed up with a lab colleague, Alfred Perot (with no accent!). While Perot’s background was in thermodynamics, he was an exceptional experimentalist with a real flair for machine work and construction. Fabry looked after the optics while Perot focused on the rest. Together they built a device similar to Bolouch’s.

The crucial insight was that the silvering caused multiple reflexions of the light between the faces. As the number of reflexions rose, so did the sharpness of the lines. The key parameters were the separation of the mirrors, the refractive index of the gas (or vacuum) between them, and the degree of silvering of the faces. This allowed the interferometer to be used in several ways. As a spectroscope, the fringes allowed very precise measurement of the wavelengths of spectral lines. Their instrument had a resolution far exceeding any grating, or even the rival Michelson interferometer (CK74 October 2013). While Michelson’s device required a whole table, Fabry and Perot’s cavity could be held in one’s hand. With it, they resolved several previously unobserved hyperfine lines in the spectra of several elements.

But the device could also be used to measure lengths to a precision of less than a wavelength. This required determining the order of the fringes. This was done by monitoring a pair of spectral lines – as the separation between the plates was changed the lines overlapped and separated periodically just as in a Moiré pattern of overlaid sieves or fabric. The resolution was so good, that the pair began to refer to their device as an “étalon” or reference gauge, a word that has stuck ever since. It

is telling of the exquisite resolution of the etalon that the metre would come to be defined in terms of wavelength of a particular transition of atomic krypton.
Astronomers began to put etalons between the objective and the camera to record stellar spectra, which probably delighted the one-time astonomer. Today, if you buy a “solar filter” for a home telescope, what you get is a Fabry-Perot etalon, the spacing selected to act as a narrow band-pass filter for the alpha line of hydrogen. In many ways lasers (CK88, Dec 2014) can be thought of as Fabry-Perot devices with one end fully silvered. Indeed laser cavities are often built with an internal etalon to make them single mode.
Fabry would make numerous other contributions, perhaps most notably discovering the ozone layer in 1915. He worked with Perot until 1921 when he became Professor at the Sorbonne in Paris, and later head of the École Polytechnique where he had started.
Today, 4 km long descendants of the original etalon sit in each arm of the Michelson interferometers of LIGO, the experiment that detects the infinitesimal distortions of our world produced by gravitational waves, hugely enhancing its sensitivity. While at home, my skylight, with its beautiful optical flaw, connects me to the very fabric of space-time itself.

References

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