Melloni's Thermomultiplier

Macedonio Melloni (1798-1854)

A few months ago, I bought a cheap infrared camera. It's a hilarious toy that can be used to map the invisible, from pipework in walls to people hiding in the night. The delight that still comes from playing with these gadgets is just a reminder of quite how mysterious the electromagnetic spectrum remains and what a surprise it must have been when it was first discovered.

An important step was taken when William Herschel, the Anglo-German astronomer decided to establish which of Newton's seven colours of the rainbow were responsible for the warmth that one feels on a sunny day. Like Newton, he set up a prism to project a spectrum of sunlight. With a blackened thermometer he measured the effect of each colour in turn. To his surprise the temperature of the thermometer rose as he moved from the violet to the red, but actually reached a maximum in a position beyond the red. As he put it "radiant heat will at least partly, if not chiefly, consist, if I may be permitted the expression, of invisible light". This led him methodically to examine the properties of these invisible rays, finding that they could be reflected and refracted just as visible light could. Yet although Herschel's contemporary Thomas Young was establishing the wave nature of visible light, no one immediately realised the significance of the discovery.

All this would change in 1821 when Thomas Johann Seebeck, an Estonian physicist working in Germany, discovered a curious effect: if two dissimilar metals were joined together making a pair of junctions, a current flowed if the junctions were held at different temperatures. In Italy, the physicist Leopoldo Nobili (1784-1835), working in Reggio Emilia, began to investigate. He built a chain of alternating soldered bars of antimony and bismuth, assembled into an array using mastic. He also designed a new "astatic" galvanometer with two oppositely magnetized needles suspended on a torsion thread, one inside the coil and one outside that compensated for the earth's magnetic field. When one side was warmed the resulting current was measured by the kick of the needle above a circular scale. Nobili proposed his "thermoscope" as a new way to measure to temperature. While he was doing this work, Nobili began to correspond with a young man Macedonio Melloni, who was based in Parma, just a few miles away. Melloni had grown up in Parma, spending his summers out in the countryside exploring and reading books under the trees in the summer heat. He became fascinated by the seasons and the alternation of hot and cold. His obsession with heat had led him to a teaching post at the Royal College. When he heard about Nobili's device he seems to have realised that it offered a way of measuring not temperature, but the intensity of radiant heat and with Nobili's encouragement, Melloni began to improve the thermoscope.

Melloni assembled the chain into a block of up to 38 bars each 20 mm long and a millimetre or two across. Insulated with paper, and soldered in alternating series, the block of rods sat in a small copper box, the faces were painted with lamp-black to better absorb the heat. Two wires led to a galvanometer of his own, improved, design.

Melloni soon realised that the radiation was everywhere. The device's sensitivity was unmatched and so was its speed. He could detect the warmth of a person standing 10 meters away, and showed that caterpillars are warmer than butterflies. His first paper was joint with Nobili but after that he published alone. He showed that different surfaces had different emissive powers. But more importantly he was able to quantify the *diathermancy* of different solid materials – their ability to transmit heat. Blocks of rock salt were completely transparent and sheets of rock crystal (quartz) absorbed about half of the light. Iceland spar, the calcite crystals used to polarize light (see Nicol CK106, June 2016) and glass, were almost completely opaque.

But Melloni's research was disrupted by his political activism. His radical views forced him to flee Parma in 1831, first for Geneva and then for Paris. He visited London in 1834 where he was awarded the Royal Society's Rumford Medal on the recommendation of Michael Faraday.

In the late 1850's Faraday's successor at the Royal Institution in London, John Tyndall revisited Melloni's work. He meticulously measured a series of liquids, using the thermopile. He then surveyed gases. The reason was Joseph Fourier and Claude Pouillet's suggestion that some component of the atmosphere was responsible for setting the temperature at the surface of the earth. What was that component?

Needing transparent windows he posted a message in the Philosophical Magazine asking for rock salt. Herschel's son, John, the Astronomer Royal, immediately sent him a block from which he had earlier fashioned lenses and prisms to study the optics of the radiant heat. Tyndall cemented two salt discs at either end of a tube which he could now fill with different gases. With a metal cube filled with boiling water at one end as a heat source, he could measure the radiant heat at the other with the pile and galvanometer. But when he saw almost no change when his tube was filled with air, he made an exquisite modification. He placed an identical heat source on the *other* side of the pile and with the tube under vacuum, set the galvanometer to zero. With this differential method he could measure the most delicate change in intensity due to gas in the tube. On 24 November 1859 Tyndall filled a tube 3 feet 5 ¼" in length with dry carbonic oxide (CO_2) and observed a huge absorption. He had identified the gas responsible for Fourier's "greenhouse".

Melloni returned to Italy in 1939, but to Naples rather than Parma. He died of cholera in an epidemic in 1854 and today few know his name. But by making Herschel's "invisible light" visible he invented climate science. Like Melloni it has moved from the scientific to the political. Perhaps infrared cameras aren't just toys after all.

Reference

L. Nobili and M. Melloni, *Ann. Chim. (Phys.)*, **1831**, *48*,198-20