Michael Faraday's Use of Platinum in His Researches on Optical Glass

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In 1824, the British government sought to keep pace with continental advances in optical glass manufacture by funding research into the area. Faraday was put in charge of the experimental investigation and he relied heavily on platinum for vessels and instruments. Throughout the researches he was aided by William Hyde Wollaston, who manufactured and supplied the platinum initially used.

In the first quarter of the 19th century British astronomers were becoming increasingly worried, as they perceived their leadership in observational astronomy shifting decisively to continental rivals. Ever since Peter Dollond had developed and marketed achromatic lenses for telescopes, from 1758 on, British astronomers were confident that they were able to purchase, from domestic craftsmen, telescopes with the best optics in the world. By 1825, however, reports from continental Europe suggested that English telescopes were no longer superior to German or French ones, and the fruits of astronomical discovery seemed sure to follow the lead of technological supremacy. David Brewster, the caustic editor of the Edinburgh Journal of Science, reacted to Wilhelm Struve's description, in 1826, of the newly installed refracting telescope in the Observatory of Dorpat as "the most perfect optical instrument yet in existence" with an editorial postscript that warned of the dire consequences:

> "... we think that no Englishman can read it [the description of Dorpat's telescope] without feelings of the most poignant regret, that *England has now lost her supremacy in the manufacture of achromatic telescopes*, and the government one of the sources of its revenue. In a few years she will also lose *her superiority in the manufacture of the great divided instruments for fixed observatories.* When these sources of occupation for scientific talent decline, the scientific character of the country must fall along with them, and the British government will deplore, when it is too late, her total inattention to the scientific establishments of the empire. When a great nation ceases to triumph in her arts, it is no unreasonable apprehension, that she may cease also to triumph by her arms." (1)

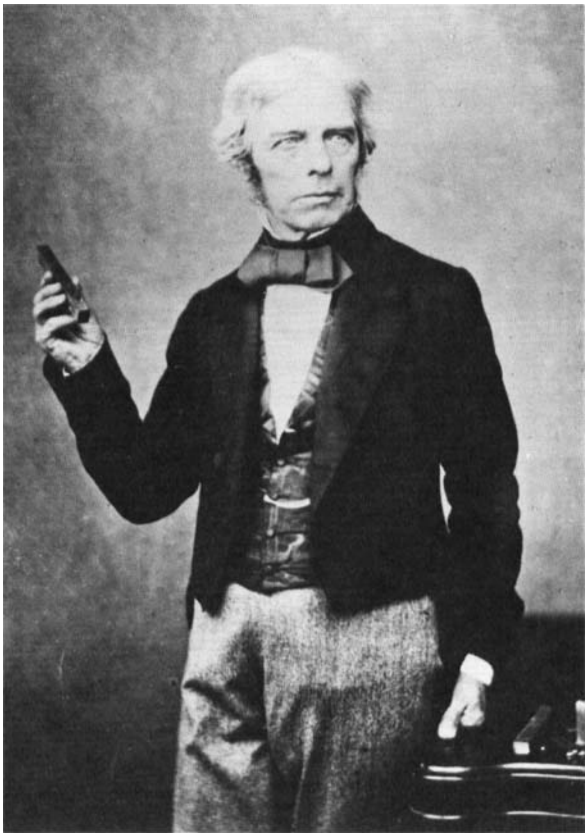
The astronomer James South was of a similar opinion after viewing the achromatic telescope in the Royal Observatory of Paris in 1826:

> "I have no hesitation in saying, that this telescope is the best achromatic I ever pointed to the Heavens; nor will I withhold my regret, or even the mortification I feel in asserting, that England, when I visited it in May last, could not produce an achromatic any thing like it." (2)

Hoping to re-establish the vitality of British astronomy, the government in 1824 funded research into the manufacture of optical glass for achromatic lenses through a committee of the Royal Society. After consultation with members of the Board of Longitude, the committee appointed Michael Faraday, John Herschel and George Dollond to investigate thoroughly the manufacture of optical glass (3). Faraday carried the responsibility for the chemical part of the investigation and platinum, he concluded, was vital to a successful result.

Flint Glass before Faraday

Although Newton had concluded that refraction of light by glass lenses was always accompanied by dispersion, John Dollond in the



Michael Faraday
1791–1867

Several of Faraday's many contributions to the advancement of science involved the platinum metals. He was a frequent visitor to the Hatton Garden premises of Johnson Matthey, from whom he obtained supplies of these metals, and was one of those sponsoring Percival Norton Johnson for election to the Royal Society. Following early researches with James Stodart on the effects of adding platinum metals to steel, Faraday was commissioned by the Royal Society to investigate means of improving the quality of optical glass, a piece of which he is holding

By courtesy of the Royal Institution

1750s undertook a series of experiments which demonstrated that the dispersion caused by a convex lens of low density crown glass could be corrected by a concave lens of higher density flint glass. In 1758 Dollond was granted a patent for his novel achromatic doublet, which consisted of a convex crown lens cemented to a concave flint lens, and in 1763 his son, Peter, made the first triple achromatic lens, consisting of a concave flint coupled with two convex crowns. Astronomers were delighted with Peter Dollond's achromatic lenses, and demand for his telescopes quickly spread across Europe.

Dollond's output of achromatic lenses was limited, however, by the shortage of suitable flint glass blanks. Because flint glass contains a high proportion of lead it is very difficult to obtain large homogeneous blanks. Thus, most lenses of the time were small and of relatively poor optical quality, often containing small bubbles and density gradients, and tints due to metallic impurities. Very rarely were discs larger than 4 inches in diameter suitable for lenses, and those that were, were sold only to privileged customers. So increases in the size of achromatic telescopes and improvements in their optical resolution both awaited the manufacture of high-quality flint glass.

In England, however, the manufacture of all types of glass, even on the smallest scale, was subject to a debilitating excise duty. The excise regulations in Faraday's time required

> "Every annealing oven, arch or lear ... for annealing flint glass to be made of rectangular form with the sides and ends perpendicular and parallel to each other and the bottom thereof level and with only one mouth or entrance, with a sufficient iron grating affixed thereto and proper locks and keys and other necessary fastenings. Twelve hours' notice to be given before beginning to fill or change any pot for making glass. . . .

> Six hours' notice to be given in writing of intention to heat any oven, arch or lear into which any glass is intended to be put for annealing. In all glass chargeable by weight, the grating to the annealing arches to be closed and securely locked and sealed by the [excise] officers immediately after all the glass or ware have been deposited therein." (4)

John Dollond, for example, had concluded that it would be impossible to carry out experiments on glasses of various refractive indices under the regulations of the Excise Act.

While the British glass industry thus stagnated, a Swiss cabinet-maker named Pierre Guinand taught himself the basics of glass manufacture and began trial melts of flint glass about 1783. After producing some fine 4 and 6 inch discs, Guinand in 1805 began to produce larger discs of exceptional quality, principally due to his use of a fireclay stirrer, which he used to keep the molten glass well mixed until, upon cooling, it became too viscous (5). Later, he developed the method of making large optical blanks by pressing softened homogeneous glass into a circular mould, and discs of 12 inches in diameter became a possibility. Guinand passed his techniques on to Joseph Fraunhofer, a brilliant optician who began to accurately measure the refractive indices of his lenses using the monochromatic yellow light of a sodium lamp (6). Soon Fraunhofer began to design and construct achromatic object-glasses that surpassed the best English specimens, and which still compare well with modern lenses. The Dorpat refractor, which so aroused the envy of the British, was an outstanding example of Fraunhofer's ability and remained for many years, with its 9½ inch object-glass, the largest refractor in the world.

Faraday's Researches

In response to this threat from abroad, the British government agreed to remove the restrictions on glass and to "bear all the expenses of furnaces, materials, and labour, as long as the investigations offered a reasonable hope of success (7)" and, as mentioned previously, Michael Faraday was appointed to the research. In 1825, the experiments began at the Falcon Glass Works of Apsley Pellat and James Green, but were transferred to the Royal Institution in September 1827, at which time a suitable room with furnaces was provided for Faraday's convenience (8). Faraday continued his investigation for four years, and the results were reported in the Bakerian lecture of the Royal Society for 1829, published in 1830 (9).

Early in the work, Faraday recognised that the greatest problems in flint glass manufacture were caused by lead oxide, which comprised nearly one-third of the weight of the glass. In the original melt the lead oxide tended to sink to the bottom, leaving an inhomogeneous glass full of striae. Faraday preferred instead a new glass, which he termed

> "a silicated borate of lead, consisting of single proportionals of silica, boracic acid, and oxide of lead. The materials are first purified, then mixed, fused, and made into a rough glass, which is afterwards finished and annealed in a platina tray" (10).

The use of a platinum tray as a vessel for the final stages of the glass manufacture was a unique innovation, one possible in England where malleable platinum was available (although only in small amounts) from first William Hyde Wollaston, and then Percival Norton Johnson. Faraday found that the platinum sheeting served well as a vessel for molten glass.

> "Platina also was ultimately found to answer perfectly the purpose of retaining the glass: for though at first it was continually liable to failure, yet it was ultimately ascertained that neither the glass nor any of the substances entering into its composition, separate or mixed, had the slightest action on it." (10)

The platina to be used, Faraday advised,

> "should be of such thickness as to weigh at least 17.5 grains to the square inch [this corresponds to a thickness of 1/250 inch]; and it is important that in its preparation a good ingot or the good part of an ingot of platina has been selected, and that it has been rolled very gradually and carefully without the formation of any holes by the adhesion of dirt or hard particles, or by the dragging of the metal in the mills. The desired perfection is, I understand, best obtained by

Some of the pieces of optical glass made by Faraday during his investigation of ways of improving the quality of glass for telescopes. The paper presented to the Royal Society described his use of platinum for the construction of vessels and instruments in contact with molten glass and also its use in powder form to eliminate bubbles from the glass

By courtesy of the Royal Institution

> rolling the platina between two clean plates of good copper" (11).

The largest glass blank Faraday produced was 7 inches square and 0.8 inches thick, and required a platinum sheet 10 inches square which had been folded into a square tray. He was able to use the platinum trays for more than one glass blank by carefully placing the folds in new positions, or by using the platinum sheet for glass blanks of ever decreasing size. Such platinum vessels maintained the purity of the glass melted in them, and were an improvement over the porcelain or earthenware crucibles generally used.

A second important application of platinum was in the stirrer, which by necessity had to be rigid and strong, and chemically inert to the molten glass. Faraday designed a stirrer with a platinum blade

> "6¼ inches in length and ¾ths of an inch in breadth. It is perforated with various irregular holes, that, when drawn through the glass like a rake, it may effectively mix the parts. A piece of thick platina wire, about thirteen inches long, is riveted to it, and the extremity of this screwed into the end of a clean iron rod which answers the purpose of a handle" (12).

A third role for platinum was as a centre of nucleation for gas bubbles, with the metal in spongy, powdered form. Faraday had observed that, in unstirred glass, tiny bubbles often flawed the final product. By adding 7 or 8 grains of spongy platinum (carefully prepared by Wollaston's published procedure of 1828) to each pound of glass, the platinum

> "was found to assist powerfully in the evolution and separation of the bubbles, and afterwards to sink so completely to the bottom, that not a particle remained suspended in the mass . . . and in every case since its use, where stirring has not been necessary, the resulting glass has proved to be perfectly free from bubbles" (13).

In addition to these uses of platinum, Faraday often used a platinum ladle which was simply constructed by riveting a platinum crucible to a platinum wire, which was in turn attached by a screw to an iron rod handle.

Thus, aside from his formulation of a new "silicated borate of lead" glass, Faraday's major innovations to the techniques developed and held in secrecy by Guinand were the use of platinum vessels for the molten glass, platinum instruments for the stirring and transfer of the glass, and platinum powder for the elimination of bubbles. The importance of platinum to Faraday's process is such that one suspects he believed from the outset that the inert metal held the key to the production of improved optical glass.

Wollaston's Contribution

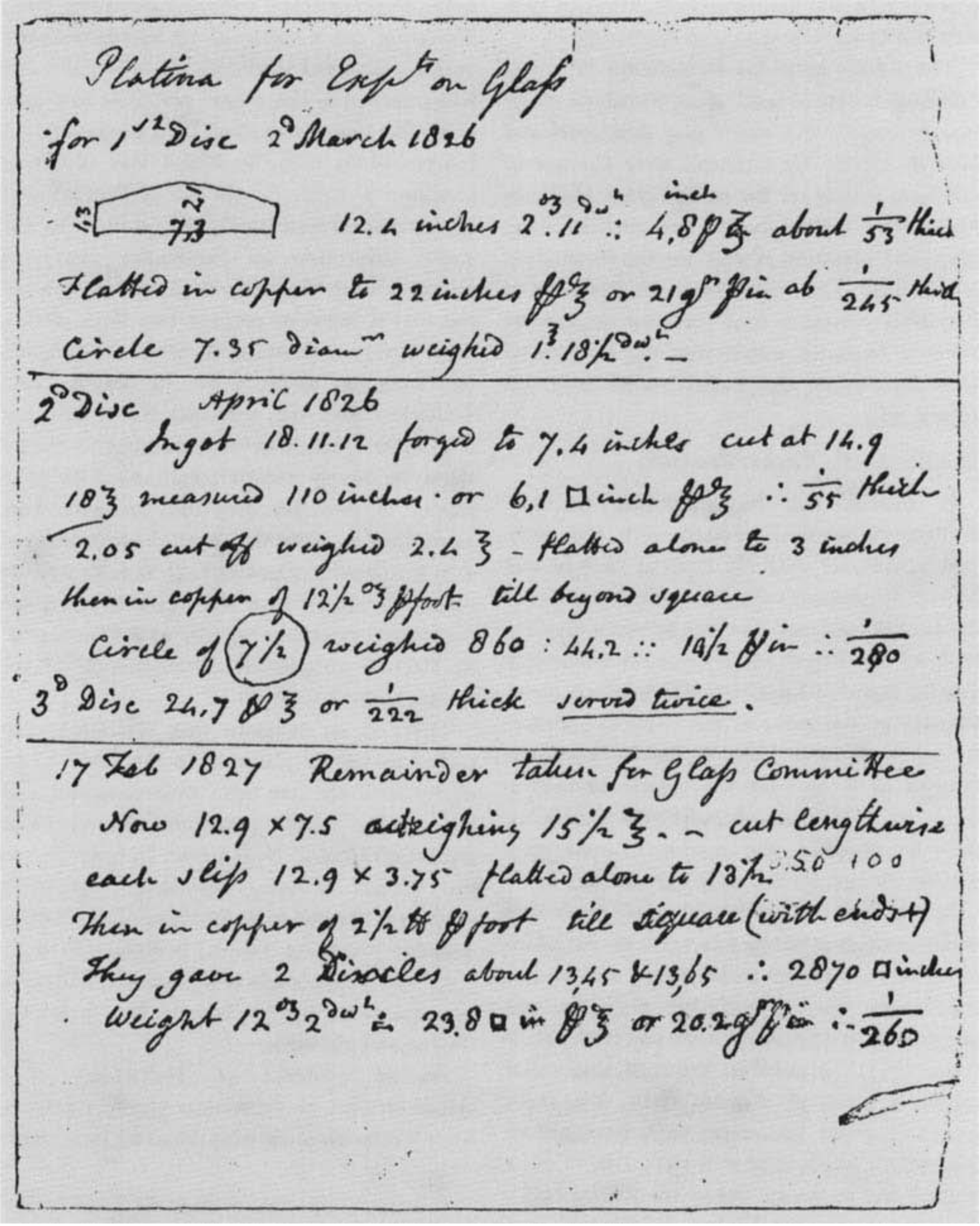
It should not be surprising to find Wollaston's name connected with the early experiments, for until his death in 1828 he was constantly seeking to broaden the commercial market for platinum. Further he was a member both of the Royal Society's select committee and the Board of Longitude which jointly chose Faraday as a member of the Glass Committee. It may well have been Wollaston who first thought of using platinum vessels for molten glass, for in his research notebooks is evidence that he supplied the platinum, apparently without charge, for the early experiments.

By the 1820s Wollaston could no longer obtain enough crude platina to fill his outstanding orders for boilers and siphons, and his last production run of malleable platinum was carried out on 2040 oz. of scrap and remnants in 1820/21 (14). Nearly all the malleable metal produced went to William Cary, but three ingots of about 18 ounces each remained in Wollaston's hands in March 1825. One of these is recorded as being "taken for Pellatt" (15). Elsewhere in the notebooks is a folded sheet of paper detailing the preparation of this platinum ingot for the "Glass Committee" in April 1826 (16). The ingot was flatted to a thickness of 1/55 inch, resulting in a sheet 14.9 inches long and 7.4 inches wide, weighing 18 ounces. From this a strip 2.05 inches wide was cut from the length, "flatted alone to 3 inches [in width], then in copper of 12½ oz. per [square] foot till beyond square" (17). From the resulting sheet, Wollaston cut a circle of 7½ inches diameter with a calculated thickness of 1/280 inch; this was recorded as the second disc. The first disc, of similar dimensions, had been prepared on 2 March 1826; thus Wollaston was supplying platinum to Pellat for the use of Faraday well before the experiments were shifted to the Royal Institution (in September 1827). In February 1827 Wollaston used the remainder of the flatted ingot to prepare two large circles, each having a diameter of about 13.5 inches and weighing about 6 oz. In March 1827, Wollaston took the remnants from these last two circles, which he characterised as "being shreds & nearly useless", and rolled them in copper to give five very thin (ranging from 1/410 inch to 1/865 inch in thickness) circles of 4 to 5 inches in diameter (18). It is likely that these thin sheets were placed under the glass-containing platinum vessels, as recommended by Faraday to prevent contamination of the vessels by their support.

There is no evidence that Wollaston continued to supply platinum to the Glass Committee after the one ingot was consumed, and for further work platinum was probably purchased from P. N. Johnson. In his paper on the subject Faraday mentions "the great expense of the material: the value of the plate in question [weighing 3.6 oz.] is about £6 10 *s*". (19). This corresponds to a price of about 36 *s*. per oz., twice Cary's usual selling price for Wollaston's platinum.

Further evidence of Wollaston's close collaboration with Faraday is given by a letter from Wollaston to Faraday dated 27 June 1828:

> Dear Sir,
>
> I called, some days since at the Royal Institution & not finding you at home left for you with the porter the bottom of the crucible containing the lead in hopes that you would examine how little has been lost—
>
> I now send the glass which has been slit & polished for examination but have retained a thin slice from the bottom for the purpose of shewing to Mr. Pellatt how very little even of the glass is contaminated thereby.
>
> Your much obliged
> W. H. Wollaston.



Platina for Exp^{t} on Glaſs

for 1st Disc 2^{d} March 1826

1.3 2 7.3 12.4 inches 2^{oz}.11^{dwt} ∴ 4,8 p ℥ about $\frac{1}{53}$ thick

Flatted in copper to 22 inches p ℥ or 21 g^{r} p in ab $\frac{1}{245}$ thick

Circle 7.35 diam^{r} weighed 1$^{℥}$ 18½ dw^{t} –

2^{d} Disc April 1826

Ingot 18.11.12 forged to 7.4 inches cut at 14.9

18 ℥ measured 110 inches · or 6,1 □ inch p ℥ ∴ $\frac{1}{55}$ thick

2.05 cut off weighed 2.4 ℥ – flatted alone to 3 inches

then in copper of 12½ oz p foot till beyond square

Circle of 7½ weighed 860 : 44.2 :: 14½ p in ∴ $\frac{1}{280}$

3^{d} Disc 24.7 p ℥ or $\frac{1}{222}$ thick served twice.

17 Feb 1827 Remainder taken for Glaſs Committee

Now 12.9 × 7.5 weighing 15½ ℥. – cut lengthwise

each slip 12.9 × 3.75 flatted alone to 13½ 50 100

Then in copper of 2½ lb p foot till square (with [illegible])

They gave 2 Circles about 13,45 & 13,65 ∴ 2870 □ inches

Weight 12^{oz} 2^{dwt} ∴ 23.8 □ in p ℥ or 20.2 g^{r} p in ∴ $\frac{1}{260}$

This loose sheet, inserted in one of William Hyde Wollaston's notebooks, records some of his work during the preparation of thin discs of platinum for use by the 'Glass Committee'

By courtesy of the Syndics of Cambridge University Library

Although the details of the letter are difficult to interpret, it is clear that Wollaston was taking an active part in the chemical analysis of the optical glasses as late as June 1828, just a few months before a brain tumour caused his death on the 22nd of December.

The importance of platinum to the potential success of Faraday's research, quite likely foreseen by Wollaston, was recognised by Davies Gilbert, who read, as president of the

Royal Society, the citation for Wollaston's Royal Medal in 1828. The award, given for the process of rendering platinum malleable, was criticised by some who felt that Wollaston was undeserving of a scientific award because he had profited by the process while holding it secret (20). Gilbert, one suspects, was eager to diminish such criticism by emphasising the value to science of Wollaston's process. His citation read, in part:

> "To these scientific and beautiful contrivances [Wollaston's platinum process], we owe the use of a material, not only of high importance to refined chemistry, but now actually employed in the largest manufactories for distilling an article of commerce so abundant and cheap as sulphuric acid. And, above all, we owe to them the material which, in the skilful hands of some members of this Society [chiefly Faraday's], has mainly contributed to their producing a new species of glass which promises to form an epoch in the history of optics" (21).

Faraday's Optical Glass

Faraday's optical glasses were not, unfortunately, to usher in the new "epoch in the history of optics" that Davies Gilbert had anticipated. Although the glasses were quite homogeneous and free from flaws, they performed no better than the glasses produced more cheaply by standard techniques. Even though a report by the Committee for the Improvement in Optical Glass presented in 1831, stated that

> "The telescope made by Mr. Faraday's glass has been examined by Captain Kater and Mr. Pond. It bears as great a power as can reasonably be expected, and is very achromatic. The Committee therefore recommend that Mr. Faraday be requested to make a perfect piece of glass of the largest size that his present apparatus will admit, and also to teach some person to manufacture the glass for general sale" (22),

Faraday lost enthusiasm for glass-making and turned to his more productive electrical researches. His general opinion on the matter was that "the best step to ensure improvement will be to take off the Excise duty" (23), which the government finally did in April 1845. Only then did Britain, drawing on the expertise of foreign craftsmen, re-establish her pre-eminence in glass manufacture.

Acknowledgements

The portrait of Faraday, the picture of his glass pieces and the Wollaston letter printed on page 179 are published with the kind permission of the Royal Institution. The page from Wollaston's notebook is reproduced by courtesy of the Syndics of Cambridge University Library. The research was made possible by a grant from the Social Sciences and Humanities Research Council of Canada.

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