correcting the spherical aberration and the other for correcting the astigmatism. This is usually the method adopted by Rudolph in the earlier of the Zeiss lenses and several of the recent lenses by other makers.

Hugo Schroeder and Stuart, of Ross and Co., were the first to take advantage of the new Jena glasses, and in 1888 they patented the "concentric" lens, composed of a flint and a barium crown. It was corrected for astigmatism, but had a lot of spherical aberration. Dr. Clay reviews briefly the series of Zeiss lenses—Planar, Protar, Unar, and Tessar—made by Ross under license, and in this connexion tells the following significant story:

In 1911, when Zeiss had finished their factory at Mill Hill, they gave Ross notice to terminate the license, and themselves made the Tessar—the only one of which the patent was still running. This is rather an illuminating fact. It must be remembered that in 1892, when Ross started making the Zeiss lenses, Ross had a great name as makers of photographic lenses, while Zeiss's were practically unknown in that connexion, and undoubtedly Ross's reputation helped to make the new lenses known; yet no sooner are Zeiss ready to make their lenses over here than they terminate the contract! No further comment is necessary.

An interesting summary follows, which we have not space to notice in detail, of a brilliant series of lenses produced by Ross from 1892 to the present day. Dr. Clay says: "One other achievement of this firm I must refer to. When the Air Force began to take aerial photos in the war they found the Ross-Zeiss Tessar, of 8½-in. focus, suitable, but soon wanted great numbers, and also asked for a longer focal length lens with perfect definition over a small angular field, *e.g.* a 20-in. lens to be used with a 5 by 4-in. plate. This was wanted urgently, and in a single fortnight the lens was recalculated, and the 'Airo-Xpres' lens evolved in November 1918, working at f/5·6. Messrs. Taylor, Taylor and Hobson also made a variety of the Cooke lens, the 'Aviar,' for the same purpose."

We have not space to deal more than hurriedly with the fascinating record that Dr. Clay gives of the other work done in Britain in the development of the photographic lens to its present stage of wonderful achievement. An interesting account is given of the lenses introduced by the firm of Dallmeyer, and special attention is directed to the striking advance represented by their telephoto lenses. The original patent for the telephoto was taken out in 1891. Another English firm, R. and J. Beck, Limited, it is interesting to note, were the first to apply the iris diaphragm to photographic lenses, as early as 1882. In 1906 Beck introduced their "Isostigmar Universal," and in the following year their Isostigmar portrait lens. "These lenses do not obey the Petzval condition—that the sum of the power of the lenses, divided by their refraction index, should be zero—and were constructed by omitting this from consideration, as they believed it was not essential for a flat anastigmatic field"—a view afterwards confirmed by the investigations of W. Elder. The Isostigmar is of interest, as it covers a field of 85 to 90 degrees at f/16, the first wide angle with such an aperture. Beck also introduced another simple idea—the use of magnifiers in front of a lens—made for their Frena camera in 1894.

We have left till the last not the least of the British achievements in the development of the photographic lens—the Cooke lens invented by W. H. Dennis Taylor and made and put on the market by Taylor, Taylor and Hobson, Limited. Dr. Clay says: "I do not think the great step which the Cooke lens marks is as well appreciated here as on the Continent. The introduction of this lens has formed the starting-point for a new method of lens construction which has had, and will continue to have, many fruitful applications." The germ of the invention is thus expressed by Dennis Taylor:

It . . . occurred to the author that since the normal curvatures of images due to any lens, whether simple or compound, are fixed by its refractive indices and power alone, and are independent of the state of rays entering the lens, whether convergent, divergent, or parallel, then it should follow that the normal curvature errors of an achromatic and aberration-free collective lens should be neutralised by the normal curvature errors of an achromatic and aberration-free dispersive lens of the same power (and made of the same glasses), placed at a considerable distance behind the collective lens; while the combination would, *as a result of the separation* . . . yield a positive focus. . . .

The patents for the Cooke lens were taken out in 1893, 1895, and 1898. During the war the special Aviar lens, referred to above, was evolved, designed by Arthur Warmisham of Taylor, Taylor and Hobson. It is a split-divergent lens, which was a conception of the inventor of the Cooke lens, but the exploitation of the idea was left to Warmisham, who was able, by making a special study of coma, to improve upon the large aperture Cooke lenses, and secure a flat field of larger area than had hitherto been found possible.

In a brief review of Dr. Clay's lecture we have had perforce to omit much of important interest, but we may conclude by re-echoing the words of the author: "In this story I think we in Britain may claim that we have borne our share, in spite of all the praise that has been lavished on the Germans."

Obituary.

PROF. HEINRICH RUBENS.

HEINRICH RUBENS was born at Wiesbaden on March 31, 1865, and received his early training at the *Realgymnasium* at Frankfurt on the Main, where he gained the School Leaving Certificate, equivalent to Matriculation, in March 1884. In the summer term of that year he proceeded to the Technical High School at Darmstadt to take up the study of electro-technics. During the following winter term and the summer term of 1885 he continued his studies at the Technical High School at Charlottenburg, but soon recognised that his ability and interest lay in the domain of pure science, and for this reason he began the study of physics. After spending the winter term (1885–86) at the University of Berlin, Rubens passed on to Strassbourg at Easter of the latter year to work under August Kundt. He followed Kundt to Berlin in May 1888, and obtained his Ph.D. there the year following. His early post-graduate career was spent as *Assistent* under Kundt at the Physical Institute of the University of Berlin, where he remained until 1896, when he was invited to the Charlottenburg Technical High School, and in 1900 he was officially elected professor at that institution. In the autumn of 1906 he was elected to a full chair of experimental physics at the University of Berlin, and to the directorship of the Physical Institute, which posts he filled during the remainder of his life. He died of leuchæmia on July 17 last.

Rubens was a member of the Berlin Academy of Science, and of many other similar bodies in his own country and abroad, including the Royal Institution, of which he was an honorary member. He held doctor's degrees (*honoris causa*) of the Universities of Leeds and Cambridge, and was a recipient of the Rumford Medal of the Royal Society.

Most of Rubens' scientific investigations were concerned with the infra-red region of the spectrum, and the logical connexion of his numerous researches is a noteworthy feature of his scientific activity. Many of the instruments used in the prosecution of his work were of his own construction, including the Rubens thermopile, and the Rubens-Du Bois spherical sheath galvanometer. He was led to the discovery of residual rays as a result of his work and measurements on the optical properties of various substances with regard to heat rays. He succeeded in reducing the previously unexplored region of about twelve octaves (from $\lambda=0{\cdot}005$ to 50 mm.) between the infra-red region of the spectrum and electrical waves, by his discovery of about seven of the missing octaves.

After his observation that a number of minerals strongly reflect infra-red waves of certain definite wave-lengths, and transmit the rest of the rays, Rubens was able to isolate rays up to a wave-length of about 0·01 mm. Repeated reflection of the radiation from such surfaces results in a residual radiation which contains certain definite wave-lengths only; *e.g.* from fluorspar (0·022 and 0·033 mm.), rock salt (0·052 mm.), sylvine (0·063 mm.), potassium bromide (0·083 mm.), potassium iodide (0·094 mm.). In part collaboration with Wood, Rubens isolated still greater wave-lengths by the quartz-lens method, in which, by virtue of the higher refractive index of quartz for these long waves than for the shorter infra-red and visible rays, and by the use of suitable diaphragms, he succeeded in obtaining rays with a wave-length of about 0·110 mm. from an incandescent mantle. Using a quartz mercury lamp he extended this limit to beyond 0·3 mm. In continuation of his earlier measurements on wave-lengths in the near infra-red, Rubens and his co-workers examined the dispersion and absorption of the whole range of the infra-red in numerous substances. By making use of the refractive indices of numerous substances found for these long wave-lengths, or the values extrapolated for infinite wave-length, he tested the validity of Maxwell's law ($n^2=k$) between the refractive index for these waves, and the corresponding dielectric constant of the substance in question. Several series of measurements on the absorption of infra-red waves in water vapour supplied him with the material requisite for the comparison of Bjerrum's theory of rotation spectra with experiment, and for calculating the main moment of inertia of the water vapour molecule.

In addition to his fundamental work on residual rays, Rubens accomplished much in other branches of radiation. He carried out measurements in collaboration with Hagen at the *Physikalisch-Technische Reichsanstalt* on the reflecting power (R) of metals, which led to the empirical result that for metals the coefficient of penetration ($P=1-R$) for very long waves can be represented by the relation $P=0{\cdot}365\sqrt{\sigma/\lambda}$, where σ is the specific resistance of the metal, and λ the wave-length of the rays in terms of the unit 0·001 mm. This result is in agreement with deductions from the electromagnetic theory of light. His investigations on the validity of the law of radiation are of primary importance. Conjointly with Kurlbaum he carried out measurements on black body radiation of long wave-length, and this work was largely responsible for a revision of Planck's first radiation formula, and thus supplied one of the experimental bases of the quantum theory. Only last year, Rubens again applied his great experimental ability in an endeavour to test Planck's law of radiation in its final form. The results of this work led to the complete confirmation of the theory. They were communicated to a Congress of Physicists at Jena in the autumn of 1921, and Rubens was acclaimed by the congress in a manner seldom met with in scientific life.

Rubens, whose wife survives him, was in failing health for some years prior to his death. To those who knew him well, it seemed that the privations attendant upon war-time conditions were in a large measure responsible for hastening the end. In addition to his great powers and achievements, his active nature and kindly disposition bound him closely to his colleagues, who realise that in Rubens they have lost much more than a valued colleague. The loss to science will be appreciated by those of other countries who came in contact with him, for one could not meet Rubens without feeling the forcefulness of a striking personality. Until his death he maintained none but the friendliest of feelings towards his colleagues in England, and during the long years of the great war he took a human interest in the well-being of those of our scientific nationals whose lot it was to be detained in enemy territory. For these he did what he could. Science mourns his loss, and the record of his active life will occupy a prominent place in the annals of science.

R. W. L.

THE opportunity is most welcome to add my expression of deep regret for the loss of Prof. Rubens at an age when much might still have been expected from his scientific activity. I well remember the enjoyment of the hospitality of himself and his family in days now past, in the residence attached to the Physical Institute of the University of Berlin, where memories of Helmholtz were evoked at every turn. One can recall the simplicity of the apparatus used in his personal investigations, in keeping with the directness of his main results. In these respects he retained throughout his career the stamp of the school of his early master Kundt.

The existence of sharply defined ranges of intense