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# In Remembrance of Otto Scherzer, the Eminent Pioneer of Electron Optics

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This year, MSA celebrates the hundredth birthday of its late Distinguished Scientist Otto Scherzer who was born on March 9, 1909 in the Bavarian town Passau. In 1927, he attended the Technical University Munich where he studied electrical engineering. After receiving his bachelor's degree, he joined the institute of the famous theoretical physicist Arnold Sommerfeld at the Maximilian University Munich. Somewhat more than two years later, at age 22, he received his Ph.D. degree. In his doctoral thesis he treated fundamental quantum mechanical properties of the Bremsstrahlung. During the economic crisis after Black Friday, Sommerfeld had no funds anymore for a post doc position. To find some support for his gifted post doc, he recommended him to Professor Ernst Brueche, who was director of research at the company AEG at that time.

The change from Munich to Berlin proved to be a stroke of luck for the emerging field of electron optics because Scherzer had the masterly ability to solve actual technological problems by means of appropriate theoretical tools. His tasks involved the design of electron lenses, deflection elements and other electron optical components used in oscilloscopes and image converter tubes. The results of his two-year investigations culminated in the book, *Geometrische Elektronenoptik*, which he published together with Ernst Brueche in 1934. This comprehensive treatise on geometrical electron optics was the standard book on the subject for many years.

By the end of 1934, the economic situation had improved considerably enabling Scherzer to return to Sommerfeld's institute, which was the centre of theoretical physics in Germany at that time. On January 1, 1936 he became Professor for Theoretical Physics at the Technical University Darmstadt making him with 26 years the youngest professor in Germany. In the same year he proved that chromatic and spherical aberrations of standard electron lenses are unavoidable [1]. His finding is so important that it was named "Scherzer theorem", which represents the only theorem in electron optics up to now. Owing to the large unavoidable spherical aberration of round lenses, the attainable resolution limit of standard electron microscopes is about hundred times the wavelength of the image-forming electrons. Decreasing the wavelength by increasing the acceleration voltage did not appreciably improve the resolution due to radiation damage caused by atom displacement.

This obstacle seemed to prevent the visualisation of the atomic world. However, Scherzer always dreamed of realizing an analytical electron microscope providing atomic resolution and giving quantitative information on the chemical and electronic composition of the object on a nanometer scale. This desire was going back to discussions with Sommerfeld who considered the electron microscope as an instrument yielding merely "coded pictures" of the object structure rather than quantitative information required by the physicists. For about ten years Scherzer was looking for possibilities enabling the correction of the unavoidable chromatic and spherical aberrations of round lenses. In1947, he found several ingenious ways to compensate for these aberrations by demonstrating that it is possible to eliminate them by lifting any one of the constraints of his theorem, either by abandoning rotational symmetry or by introducing time-varying fields, or space charges [2]. At about the same time Dennis Gabor invented holography as a method to compensate retrospectively for the unavoidable aberrations of the electron microscope by means of an ingenious light-optical reconstruction procedure. In his article dedicated to Scherzer's 60th birthday, Gabor states: "holography owes its birth to Professor O. Scherzer. It was his brilliant proof, in 1936, of the theorem that the spherical aberration can never change sign which induced me, in 1947, to look for a way around this fundamental difficulty" [3].

During that time, the actual resolution of the electron microscope was limited by axial astigmatism rather than by spherical aberration. To compensate for this astigmatism, Scherzer designed a correcting multipole element, which he called *stigmator*. This "point maker", realized by O. Rang, improved the resolution of the electron microscope considerably [4]. Scherzer considered the incorporation of multipole elements as the most promising approach for correcting aberrations. Since the experimenters in Germany did not want to perform the risky and elaborate task, Scherzer tackled the problem himself taking advantage of his own workshop, which he had required for accepting the professorship at the Technical University Darmstadt. The first approach, performed with his co-worker Seeliger [5] and later by Moellenstedt [6], showed that correction works in principle. Unfortunately, it did not improve the resolution of the electron microscope because it was limited by residual parasitic aberrations and instabilities rather than by the aberrations of the objective lens. The next approach for correcting chromatic and spherical aberrations was performed by Scherzer within the frame of the so-called Darmstadt Project. During a period of almost ten years, Scherzer and his colleagues tried to improve the information limit by improving the electrical and mechanical stabilities and by eliminating the residual parasitic aberrations. Unfortunately, the project was abandoned after his death, in 1982, although it was successful as far as it went. Schezer always believed that correction of aberrations would provide sub-Å resolution some time in the future because there is no physical law preventing it from working successfully. In 1978, at the International Electron Microscopy Meeting in Toronto, he pointed out the prime reason for the fruitless efforts by stating: "resolution is clearly limited by the unavailability of the necessary funds".

In 1948, he laid in his famous J. Appl. Phys. paper the basis for the theory of contrast transfer in the electron microscope [7]. In particular, he showed that one can visualize atoms by means of phase contrast obtained by adjusting an optimum defocus, which nowadays is known as "Scherzer focus".

Scherzer always expressed his opinion very clearly, regardless if the subject was scientific or not. During the Nazi-regime he quoted Einstein in his lectures, although this was forbidden by the administration. He fearlessly responded to the reproaches of the Nazis by saying: "if I mean Einstein, I shall say Einstein".

References

[1] O. Scherzer, Z. Physik **101** (1936) 593.
[2] O. Scherzer, Optik **2** (1947) 114.
[3] D. Gabor, Optik **28** (1969) 437.
[4] O. Rang, Optik **5** (1949) 518.
[5] R. Seeliger, Optik **8** (1951)311.
[6] G. Moellenstedt, Optik **13** (1956) 209.
[7) O. Scherzer, J. Appl. Phys. **20** (1948) 20.

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