Gertrude Rempfer
1912-2011

In 1952 at the annual EMSA meeting, Cleveland OH

Gertrude Fleming grew up in the Seattle area and was educated at the Washington State University, where, after starting in Forestry, then Bacteriology, she gravitated to Physics. Her PhD thesis was on thermionic and field-emission, which presaged her major work in photoelectron emission microscopy.

After graduation, she held positions at Mt Holyoke and then at Russell Sage college in Troy, NY, where she met her husband, Robert Rempfer, subsequently joining him at RPI. During the war, they worked at the Naval Research Laboratory on Radar counter-measures. After briefly returning to RPI, they then worked for a year on the Manhattan Project at Columbia, doing mass spectrometry for the diffusion project.

In 2011 on one of ler last visits to the lab at Portland State University

The Electrostatic Electron Microscope

Gert first seriously turned to electrostatic EM design at the Farrand Optical Company, in 1945. Farrand wanted to develop an EM, and Gert's project began with a thorough investigation of the parameters of electron lenses. This was at the suggestion of Reinhold Rüdenberg (of Ruska-Rüdenberg controversy fame), whom Farrand used as a consultant. She obtained highly accurate data by means of a grating method (shadowgraph technique) using an electron-optical bench (Fig. 1; sample images in Fig. 5), however she was not allowed to publish at the time. This outstanding work was not published until 1985 (Rempfer, 1985), but it became the basis for her future work. An experimental high-resolution electrostatic TEM was developed at Farrand, and results were shown at the 1947 EMSA meeting in Philadelphia (Flemming, 1948). A micrograph from that microscope was shown on the cover of the January, 1949 issue of the Journal of Applied Physics (Fig. 2). Unfortunately, a Farrand EM never went into production, however Gert received several patents while at Farrand, including one for real-time stereo TEM, and one for a method of correcting spherical aberration using a charged gauze window.

The Rempfers stayed at Farrand for six years, then after brief stays at Antioch and Fisk colleges (brief because of incompatibility with the Rempfers' liberal viewpoints) they returned to the Northwest, finally settling at Portland State University. There, at last having her own fully equipped lab, Gert continued her work on the electrostatic TEM. She worked in collaboration with Tektronix in the 1960s, and the result was a spin-off company, Elektros, Inc., which operated from 1969 to 1973. About 40 units of the Elektros TEM (Fig. 3) were built, and some are still in use. They were especially advantageous for third-world countries, because of their simple design, operation, and maintenance.

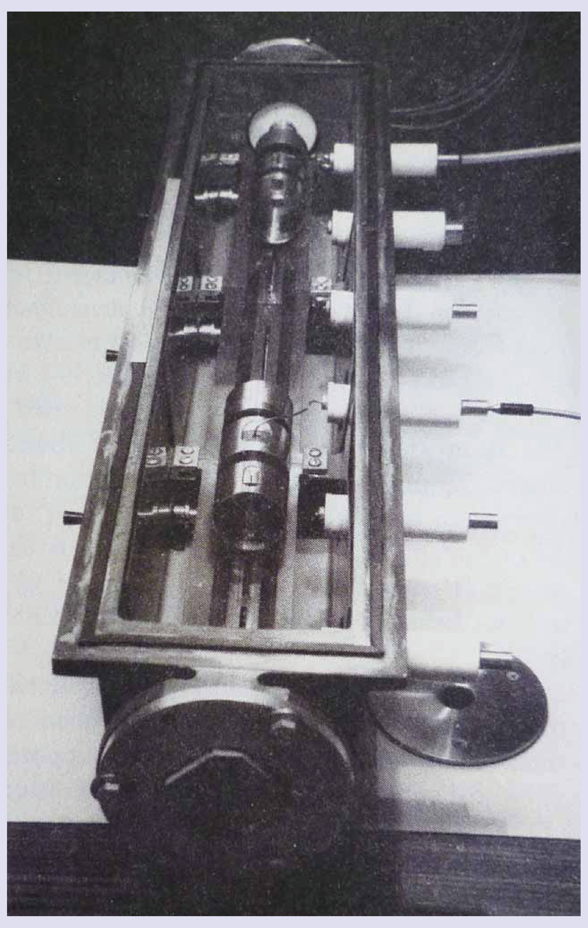

Fig. 1. One of the earliest of Rempfer's electrostatic optical benches, used to identify the optimal properties of lenses for electron microscopes.

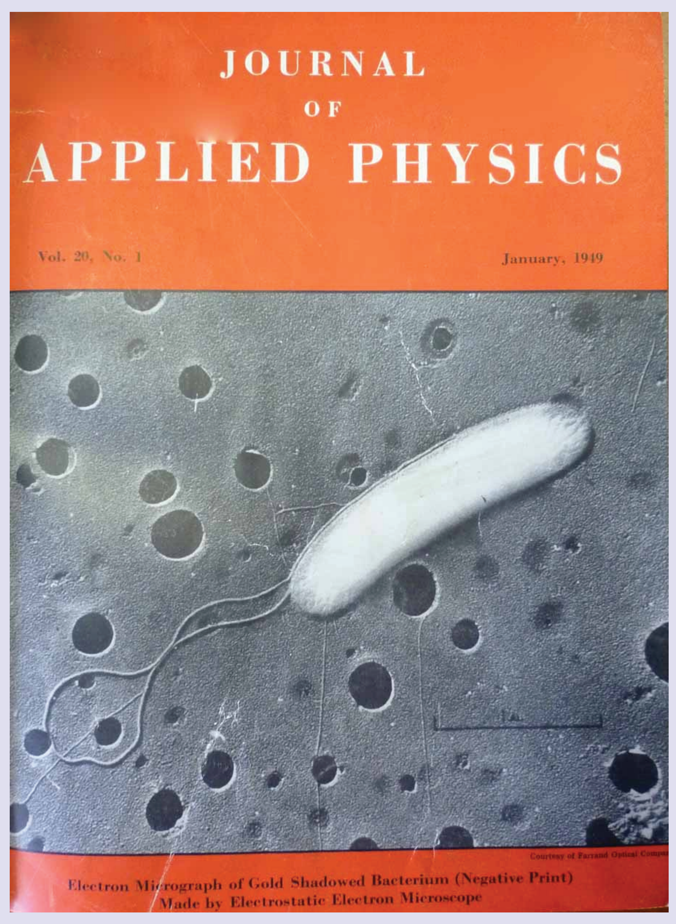

Fig. 2. Cover of the January, 1948 issue of JAP. The image, of a gold-shadowed bacterium, was taken with the experimental Farrand electrostatic TEM. It was one of the images shown at the 1947 EMSA meeting in Philadelphia.

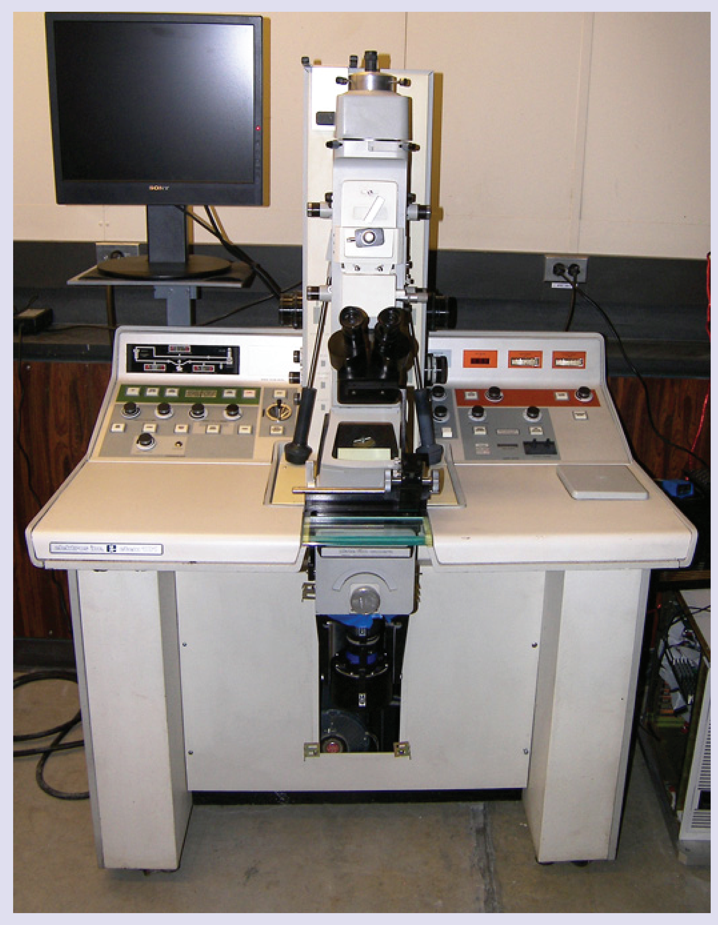

Fig. 3 An operating Elektros electrostatic TEM, located at Portland State University. The EM operates at 40 kV, and is completely self-contained, needing no cooling water. It has an automatic vacuum system and a real-time stereo imaging feature. (A modern CCD camera has been added).

The Aberration-Corrected Photo-Emission Electron Microscope

At PSU, Gert's main focus has been photo-emission electron microscopy (PEEM), which is the electron analogue of fluorescence light microscopy (Griffith et al., 1972, Rempfer et al. 1991; Fig.4). In this technique, low-energy electrons are emitted from a specimen irradiated with UV light. The electrons are accelerated and form an image in an electron-optical column.

Because of the large energy spread of these electrons, aberration correction is important, and correction by means of an electron mirror has been one of Rempfer's major interests. Mirror correction is especially suitable for the relatively low-energy electrons of the PEEM. Using a special electron-optical bench, her prime research tool, Rempfer was able to demonstrate simultaneous correction of spherical and chromatic aberrations (Rempfer et al., 1997; Fig. 5).

The work at Portland State University continued (Könenkamp et al., 2008), and a description of the most recent version of the aberration-corrected PEEM was published by Könenkamp et al., (2010; Fig. 6), achieving a resolution of 5.4 nm, far better than any other imaging method based on light illumination. Interestingly, another aberration-corrected PEEM design (properly acknowledging Rempfer's contributions) was published in the same issue (Tromp et al., 2010). The aberration-corrected PEEM at PSU is currently used for ultrafast and optical near-field microscopy in photonics and plasmonics (Fitzgerald et al.,2013).

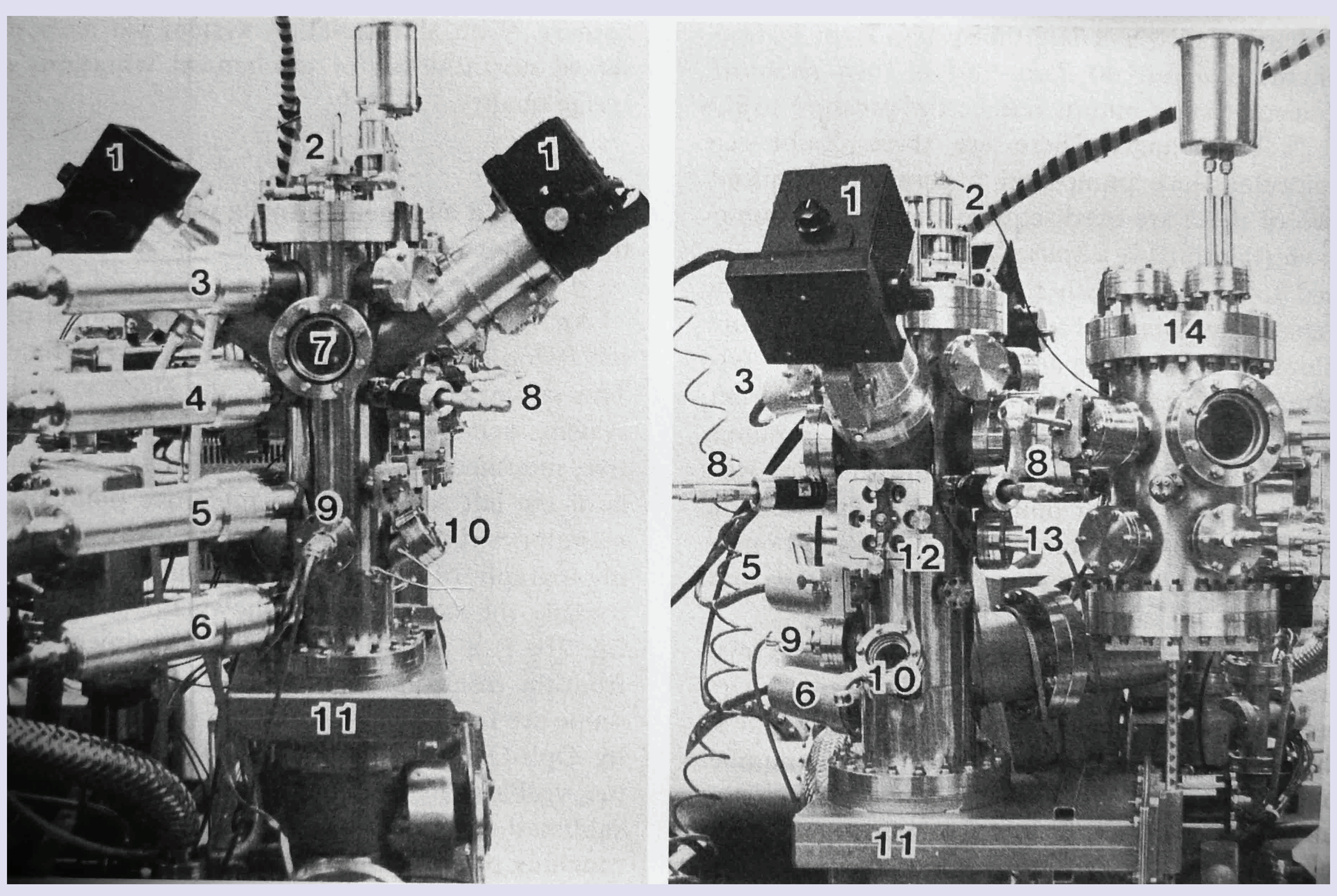

Fig. 4. The photoelectron emission electron microscope (PEEM) from 1991. PEEM requires ultra-high vacuum, with a special specimen-preparation chamber, as shown at the far right (14). The electrostatic column is on the left, with the arc-lamp housings (1) at the top, high-voltage feedthrough for the four lenses (3-6), and the camera below the gate valve (11) at the bottom.

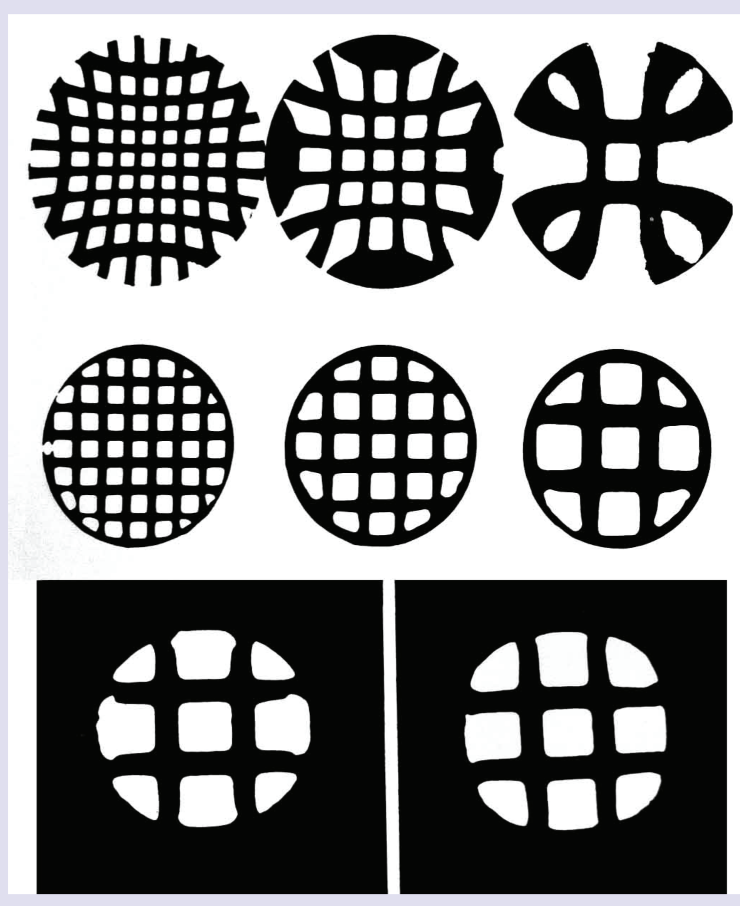

Fig. 5. Demonstration of aberration correction, from Rempfer et al. 1997. To demonstrate correction by means of an electron mirror, a Y-shaped optical bench was used that had a separator for the incident and reflected beams. The correction could easily be appreciated by imaging a fine-mesh screen. The top two rows demonstrate correction of spherical aberration at different focus settings. The bottom two images were recorded with an 18 V difference applied to the 20 kV accelerating voltage. The magnification has not changed, and the field of view has changed only slightly.

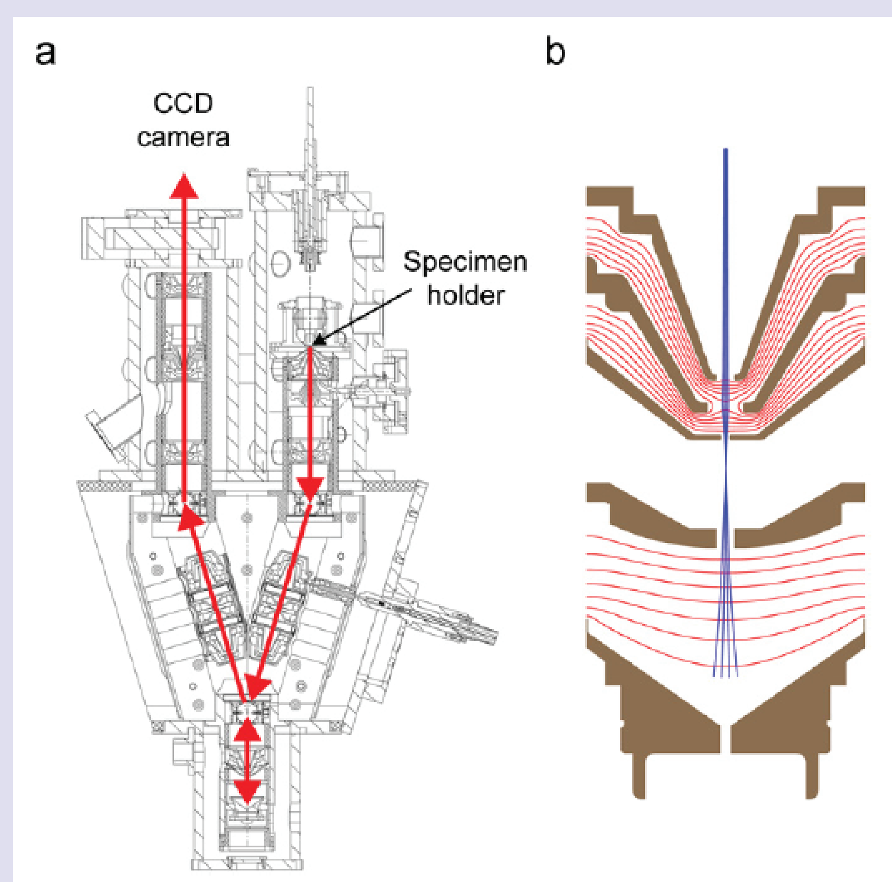

Fig. 6. Corrected PEEM instrument from Könenkamp et al., 2010. The path of electrons through the Y-shaped beamline is shown in (a), and the design of the mirror is shown in (b). The mirror is located at the bottom of the instrument, and is followed by the beam separator.

Honors

In 1987, Dr. Rempfer won the Howard Vollum Award (given in honor of the then recently deceased co-founder of Tektronix Corporation). In 1988 she won the highest honor from Sigma Pi Sigma, the physics honor society, which she joined in 1933. In 1990, Dr. Rempfer won our Microscopy Society's Distinguished Scientist award in physical sciences, the only woman so honored to date, and one the first three women Distinguished Scientists. She was honored again with a special citation at the M&M meeting in Portland in 2010. At Portland State University, Dr. Erik Bodegom, former chair of the Physics Department, created an endowed chair in the name of Dr. Rempfer. The chair is now held by Dr. Rolf Könenkamp.

Further information

A very comprehensive review of electrostatic electron optics, including EM, PEEM and aberration correction by electron mirrors, with many references to Rempfer's work, has been written by Peter Hawkes for a 2012 special issue of Ultramicroscopy:

Hawkes, P.W. (2012) Examples of electrostatic electron optics: The Farrand and Elektros microscopes and electron mirrors. Ultramicroscopy (in press: 10.1016/j.ultramic.2011.10.009)

In the same issue, Jon Orloff, who was a key member of the Elektros team, has contributed an appreciation of Rempfer's work:

Orloff, J. (2012) Gertrude Rempfer and the development of high resolution focused ion beam technology. Ultramicroscopy (in press: doi:10.1016/j.ultramic.2011.10.002)

A video clip of Dr. Rempfer talking about the Elektros TEM was made by Oregon Public Broadcasting and can be found by going to http://www.opb.org/ and searching for "Rempfer".

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