where $-e$ is the charge and m_e the rest mass of the electron. I have shown[1] that if the assumption of equilibrium orbits is valid, an electron shot axially through the magnetron will be also in radial equilibrium, that is to say, the lens effect is nil, apart from a relativistic effect. My previous suggestion, to use the magnetron as a divergent electron lens, was based on departures from the Hull–Brillouin steady state. Such departures were expected on the basis of my statistical theory of the electron cloud[4], in which radial equilibrium does not obtain at every instant but only over long intervals. It was pointed out at that time that neither the Hull–Brillouin theory, nor mine, is likely to apply under practical conditions, as both neglect electron interaction. But in the case of ion beams these differences can be disregarded, and equation 1 can be adopted, at least for a first orientation.

The radial forces of magnetic origin on ions of mass m_i are only a fraction m_e/m_i of the corresponding forces on an electron, and can be neglected compared with the radial electrostatic force, produced by the space charge, which retains its magnitude and merely changes its sign. The electric field intensity E_r at the radius r is

$$E_r = 2\pi r \rho_B = -\frac{eH^2}{4m_e c^2} r = -0{\cdot}044\, H^2 r \text{ volt/cm.} \quad (2)$$

The field is of the type required for lenses, as it increases linearly with the radius. Using the relativistic equation for the radial motion, the focal length f of a magnetron lens of length L is given by

$$\frac{1}{f} = 0{\cdot}022\, \frac{1 + 1{\cdot}06 \times 10^{-9} V/M}{1 + 0{\cdot}53 \times 10^{-9} V/M}\, \frac{H^2}{V}\, L \text{ cm.}^{-1}, \quad (3)$$

where V is the volt-energy of the ion, supposed to be single-charged, and M is its molecular weight.

As an example, consider a lens with $H = 500$ gauss and $L = 20$ cm., which requires about 8,000 amp. turns. If the radius of the anode cylinder is 2 cm. the critical voltage is 22 kV., and in practice perhaps 15 kV. may be applied before the anode current becomes noticeable. For 100 MeV. protons, that is, for $M = 1$, $V = 10^8$, equation 3 gives a focal length of 8·7 metres. By comparison, if the same coil were used, by itself, as a concentrating lens for 100 MeV. electrons, the focal length would be about 900 metres. The advantage is even greater at higher energies, as f in the new magnetron lens increases with V, as compared with V^2 for magnetic lenses and V^4 for electrostatic 'single' lenses. The only other lens types which share this advantage with the magnetron lens are the 'field lens' of L. W. Alvarez, in which the electric field terminates on a metal foil, its equivalent, recently investigated by me[5], in which the foil is replaced by a mesh grid, and the magnetic toroidal lens, recently proposed by W. T. Harris[6].

I thank the directors of the British Thomson-Houston Co., Ltd., for permission to publish this note.

D. Gabor

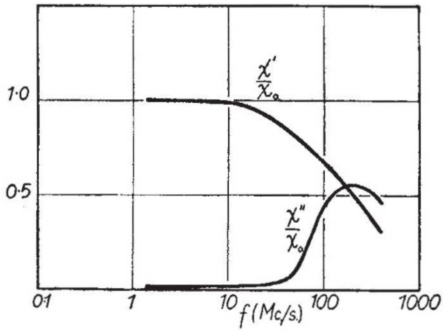
Research Laboratory,
British Thomson-Houston Co., Ltd.,
Rugby.
April 16.

---

[1] Gabor, D., "The Electron Microscope" (Hulton Press, London, 1945).
[2] Hull, A. W., *Phys. Rev.*, **23**, 112 (1924).
[3] Brillouin, L., *Phys. Rev.*, **60**, 385 (1941).
[4] Gabor, D., *Proc. Roy. Soc.*, A, **183**, 436 (1945).
[5] Gabor, D., *Nature*, **159**, 303 (1947).
[6] Harris, W. T., *Phys. Rev.*, **71**, 310 (1947).

Gyromagnetic Resonance in Ferrites

MAGNETIC ferrites of great homogeneity have been prepared in this Laboratory. In these ferrites the tangent of the loss angle between B and H is found to rise at a certain frequency fairly suddenly from values less than 1 per cent to values much exceeding unity. The permeability at the same time goes down to very low values, which shows that not only the boundary displacements but also rotation of domains as a whole are affected at these frequencies. The behaviour of the complex susceptibility $\chi_c = \chi' - i\chi''$ (see graph) suggests a phenomenon of resonance.



According to calculations made by L. Landau and E. Lifshitz[1], gyromagnetic resonance may be expected to occur in a ferromagnetic dielectric, if the frequency of the applied field equals the precession frequency of the spins around the direction of the internal field. In Landau's model the specimen is assumed to be a single crystal and the applied field is at right angles to the crystal field. Our experiments, on the other hand, were carried out on polycrystalline samples. Nevertheless, it is worth while comparing Landau's formulæ and our experimental results.

Assuming that the precession is critically damped, one easily derives from Landau's equations the following relation between the transverse susceptibility χ_t, the frequency f_h, for which the real part of the susceptibility is halved, and the saturation magnetization $I_{\max}$:

$$\frac{\chi_t \cdot f_h}{I_{\max}} = \frac{\sqrt{2}}{2\pi} \cdot \frac{e}{mc} \cdot 4 \times 10^6 \text{ cycles/Oe. sec.}$$

Evaluation of χ_t, f_h and $I_{\max}$ for the polycrystalline sample, the properties of which are shown in the graph, leads to

$$\frac{\chi_t \cdot f_h}{I_{\max}} = \frac{3{\cdot}5 \times 200}{400} . 10^6 = 1{\cdot}75 \times 10^6 \text{ cycles/Oe. sec.}$$

In our opinion the approximate agreement between theory and experiment warrants the conclusion that the rapid decrease of μ_0 in ferrites at high frequencies is probably due to gyromagnetic resonance around directions prescribed by the internal fields.

J. L. Snoek

Natuurkundig Laboratorium
der N.V. Philips' Gloeilampenfabrieken,
Eindhoven.
March 5.

---

[1] Landau, L., and Lifshitz, E., *Phys. Z. Sovj. Union*, **8**, 153 (1935).