

Dark surface plasmon modes coming to light, the history up to 1968

Andreas Otto, Institute for Experimental Physics of Condensed Matter,
Heinrich-Heine Universität Düsseldorf

In 1873 James Clark Maxwell published his famous *Treatise on Electricity and Magnetism*. At the beginning of the 20th century appeared the theory of electromagnetic surface waves. Cohn derived the dispersion relation of transverse (TE or TM) EM surface waves in 1900. They were first detected and used in telecommunication by Zennek in 1909.

There were two different approaches to the final “coming to light” of the “dark” Surface Plasmon Polariton (SPP). The first implies SPP's on metallic gratings, starting with Wood's anomalies in 1902. U. Fano introduced evanescent waves to explain Wood's anomalies and found an “energy current rolling along the surface of a metal” in 1942. The breakthrough to the dispersion of SPP's on gratings covered by Al or Au was achieved by Ritchie et al in 1968.

The second line starts with the invention of the electron transmission electrode by Knoll and Ruska in 1932, followed by electron energy loss spectroscopy (EELS) in thin films. The collective Coulomb interactions in a degenerated electron gas, called “plasma” were calculated in 1953. D. Pines gave the name “plasmon” to the quanta of the collective longitudinal (bulk) plasma oscillations and identified many characteristic losses as bulk plasmons in 1956. The final identification of the bulk plasmon was achieved by H. Watanabe in 1956 by measuring the quadratic dispersion of the Al-plasmon. In 1957, Ritchie predicted the surface plasmon identified by Powell and Swan in 1959 in electron reflection from clean Aluminum films. The first correct application of electrodynamics to surface plasmons at a metallic halfspace by A. Otto in 1967 yielded the first diagram of the dispersion of the SPP. This was followed by the application of attenuated total reflection to “bring the SPP to light” in 1968, first by A. Otto, later by E. Kretschmann and H. Raether. The name SPP was introduced at a conference in Taormina 1972 by E. Burstein.

In thin film optics, using the Kretschmann-configuration, the SPP-resonance was observed and calculated with Fresnel's equations by T. Tübbesfeld already in 1959, but not understood. Tübbesfeld's work was redetected by A. Otto in 1974.