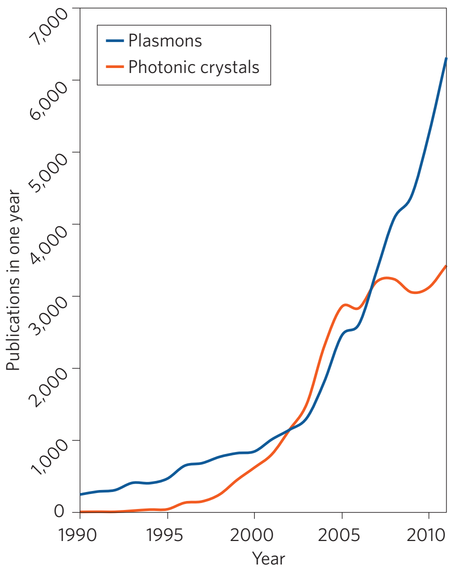
Surface plasmon resurrection

The realization that coupling of photons to charges at metal interfaces allows subdiffraction-limit localization of light has revived the field of surface plasmons. How long will it last?

This month, *Nature Photonics* presents a focus issue dedicated to the field of surface plasmon polariton photonics, or 'plasmonics'. The term plasmonics might be new, but the interaction of light with charges at surfaces is not.

Joachim Krenn, from the University of Graz, Austria, and one of the founders of the modern field of plasmonics, mentions in an interview on page 714 that people were formulating ideas over 100 years ago that still hold relevance to plasmonics researchers today. The coupling of light to charges at metal surfaces is also cited as being utilized hundreds (or even thousands) of years before that, but the science at the time was not known and the crediting of some cases (for example the coloration of some particular historical artefacts) to plasmonics may be incorrect. Following the early work of Maxwell Garnett and others in about 1904, there were periods of revival in the field every ten years or so. Using a few relevant search terms on the database Scopus shows that in the decade before 1990 about 200 papers related to plasmons were published per year. (Of course, the numbers mentioned here will vary depending on search terms and conditions, but the trends may remain similar.) Most of these papers would not be considered particularly relevant to surface plasmon photonics or plasmonics.

In the 1980s and 1990s, there were a lot of developments that contributed to the modern revival of plasmonics. In particular there was the work on surface-enhanced Raman scattering. Additionally, advances in tools for characterizing structures (scanning electron and atomic force microscopy), fabrication (electron-beam and ion-beam lithography) and nanoscale imaging of light (near-field scanning microscopy) were key catalysts for the explosion of research in the past decade or so. According to the search terms used, by around 2001 there had been a fivefold increase in manuscripts since 1990. Even then, the number of papers to read per month that were truly relevant to those working directly on modern plasmonics was manageable. However, by 2011 another fivefold increase had occurred, and within recent years plasmonics has become arguably the most populated field of research in optics.



An interesting field to compare the rise of plasmonics to is photonic crystals. After their discovery in the late 1980s, there were still only a few papers per year until about 1995 (or particularly 2000), when the field experienced a rise to the forefront of photonics. However, although there are obviously still many people publishing a large number of papers in the field, the growth collapsed in around 2004. By contrast, plasmonics has yet to show any signs of wavering. It should be noted that many of the papers revealed by the search terms that are published prior to the year 2000 are not relevant to modern plasmonics and the data should be interpreted cautiously.

The sheer number of publications in plasmonics does invite questions regarding quality versus quantity. How many of the works being published are truly novel? If a work utilizing plasmons does not exploit unique plasmonic characteristics, such as subdiffraction-limit electromagnetic field localization or unusually strong field enhancement, is it valuable or is it retelling science that could be (or has been) done without metals? There are also questions about how realistic and cautious researchers are being when writing manuscripts and making claims, particularly with respect to loss, the true confinement level of fields and related issues. This is touched on by Krenn in the focus interview and also by Malte Gather in correspondence on page 708, in which it is stressed that caution is required when making claims of plasmon lasers. That said, there is still good reason to be enthusiastic about plasmonics, with new emerging subfields such as quantum plasmonics. Also, 'classical' plasmonic fields such as plasmon waveguides, active plasmonics and metamaterials are still full of surprises.

One particular area where plasmonics is providing practically useful, and in which loss is less of a stumbling block, is that of sensors. In fact, simple frustrated total internal reflection, in the form of surface plasmon resonance on metal films deposited on prisms, has been successful for decades for bio- and chemical-sensing owing to its sensitivity and the fact that it requires only a small amount of analyte. Alexandre Brolo provides a Commentary on present effects on plasmonic biosensing on page 709 of this issue, with particular emphasis on refractive-index-based sensors.

As mentioned, one of the main features of plasmonics is the possibility of locally enhancing the intensity of electromagnetic fields. This enables strong nonlinear optical effects in structures with metal inclusions, including metamaterials. Martti Kauranen and Anatoly Zayats review the topic of nonlinear effects in plasmonic structures and present an overview of applications and limitations on page 737 of this issue.

Another review comes from Vasily Temnov, on page 728, who covers the possibilities for surface plasmons in devices utilizing the combination of magnetic, acoustic and ultrafast effects. Many researchers have high hopes for another emerging topic — graphene plasmonics — with the vision of merging plasmonics and graphene photonics to combine their useful features. On page 749, the properties and characteristics of plasmons on graphene are reviewed by Alexander Grigorenko, Marco Polini and Kostya Novoselov.

The only problem with an in-depth look at plasmonics is that it is not possible to include in a single focus issue all of the emerging or valuable topics that warrant coverage. We look forward to the future surprises in store for us from plasmonics and to highlighting them within the pages of *Nature Photonics*. ❐