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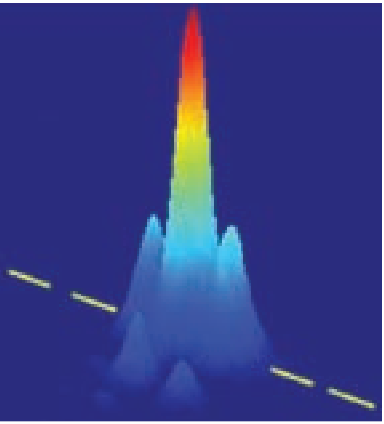
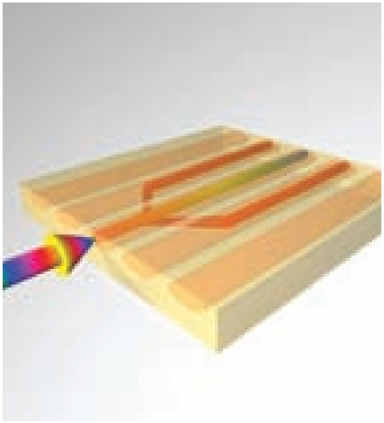
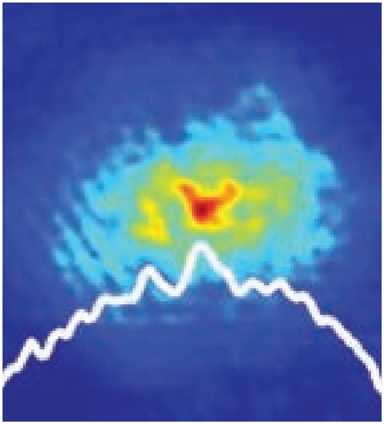
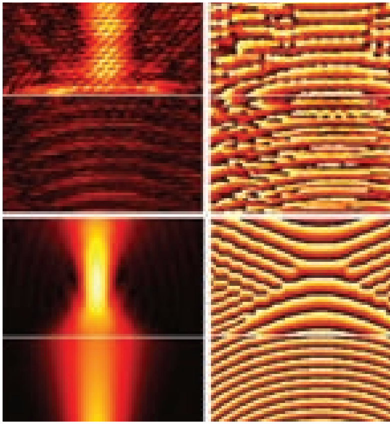








Optics in 2007

GUEST EDITORS: Robert D. Guenther, Madeleine Glick, Joseph M. Howard, Janice A. Hudgings and R. John Koshel

18 **Introduction**

19 **Biophotonics**

Optics has provided key tools for advancing both modern and traditional biology.

21 **Communications**

Although there has been a decrease in telecom research since 2000, significant optical engineering advances continue to provide important contributions to wide-bandwidth communications.

22 **Holography**

Through a careful analysis of numerically reconstructed holographic images, it is possible to obtain 3D information from a single high-aperture EUV Gabor hologram.

23 **Lasers**

Researchers have demonstrated the optical cooling of a laser.

25 **Micro-Optics**

What unique performance can be provided by micro-optical systems? Is there a limit to the reduction we can make? Researchers have taken steps to address these questions.

28 **Microscopy**

Investigators have found new ways to provide the biological community with more powerful tools.

30 **Nonlinear Optics**

Phase matching is a necessity, but what happens in the extreme? Can we use nonlinear processes to create the necessary phase matching?

33 **Photonic Structures**

The field of photonic structures now includes not only the identification of naturally occurring structures and the production of conventional optical operations, but the observation of disordered optical structures.

36 **Plasmonics**

Surface plasmons are finding interesting applications in nano-optics, where the attenuation does not dominate.

38 **Quantum Optics**

Interestingly, quantum optics is being used to solve problems in classical optics.

39 **Slow Light**

We are finally observing slow light without having to make heroic efforts.

41 **Solitons**

We can now create structures to form solitons.

43 **Ultrafast Optics**

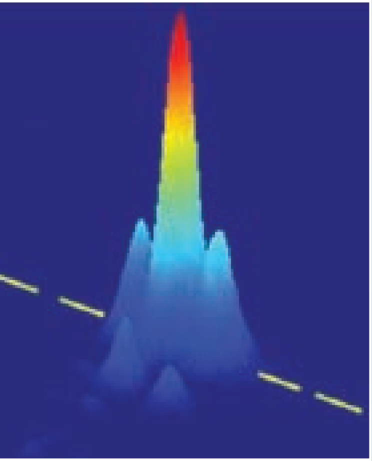
Short optical pulses provide useful material processing capability.

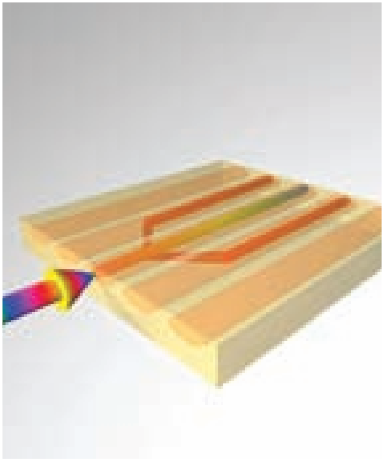
47 **Vision**

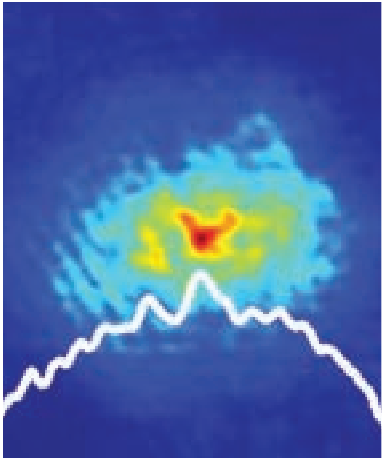
A new intraocular lens has been developed to correct coma. Another finding about metamerism shows that the eye-brain connection stills surprises.

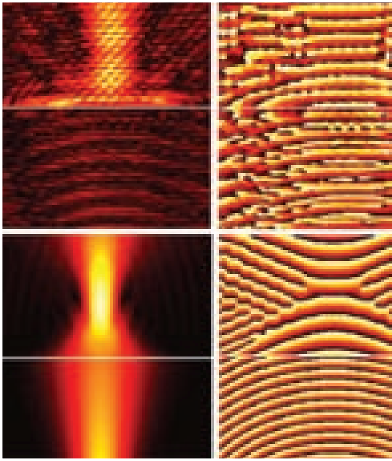
COVER: Artistic rendering of the whispering gallery mode of a toroidal resonator surrounded by single molecules. [Deniz Armani]

Optics in 2007









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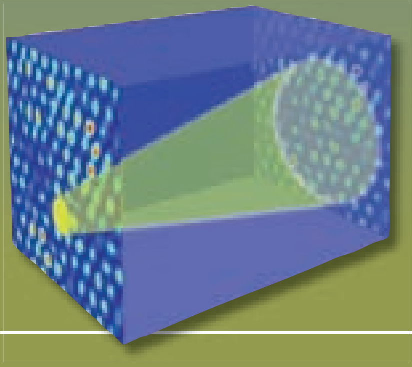


This special issue of *Optics & Photonics News* (OPN) highlights the most exciting research to emerge in the preceding 12 months in the fast-paced world of optics. "Optics in 2007" offers readers a unique opportunity to access, in a single source, summaries of cutting-edge optics research reported in the peer-reviewed press. The areas covered in 2007 include biophotonics, communications, holography, lasers, micro-optics, microscopy, nonlinear optics, photonic structures, plasmonics, quantum optics, slow light, solitons and ultrafast optics.

This year's issue comprises 30 summaries representing the work of more than 120 authors from 13 countries. Submissions were judged on the basis of the following criteria:

- The accomplishments described must have been published in a refereed journal in the year prior to publication in OPN.
- The work should be illustrated in a clear, concise manner that is readily accessible to the at-large optics community.
- The authors should describe the topical area as a whole and then discuss the importance of their work in that context.

Although OPN makes every effort to ensure that achievements in all optics subfields are recognized, there are no requirements in the selection process for inclusion of specific topical areas. When we receive a large number of submissions for a specific area, it is taken as evidence that the topic has been fertile ground for activity and research. OPN strives to ensure that engineering, science and technology are all represented.

OPN and OSA would like to thank all the researchers from around the world who submitted summaries, as well as our panel chair and guest editors.

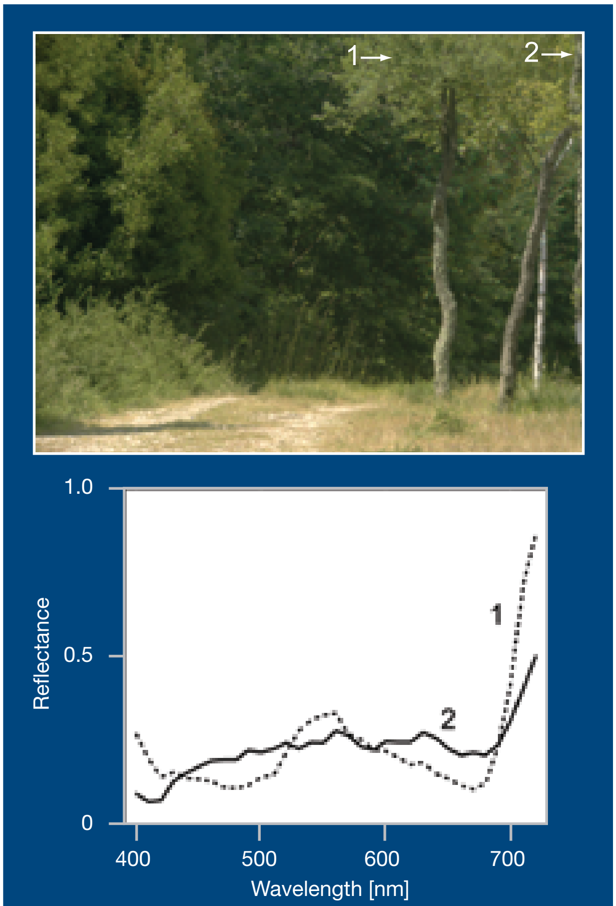
The Frequency of Metamerism in Natural Scenes

David H. Foster, Kinjiro Amano, Sérgio M.C. Nascimento and Michael J. Foster

Metamerism occurs when lights with different spectra appear the same to the eye, or, more generally, the sensor system.[1] Metamers arise because the number of degrees of freedom in a sensor system—three for the cone receptors in the normal human eye or the filters of a typical RGB camera—is smaller than the degrees of freedom needed to accurately represent light spectra.[2]

The most important example is associated with variations in surface spectral reflectances. In natural vision, these differences may be disregarded, providing that the surfaces continue to produce the same responses when the illuminant changes; visual identity is then an invariant and not an accident of viewing conditions. But metamerism becomes a problem when reflected lights become distinguishable with an illuminant change. The practical question, then, is whether metamers are common in natural scenes.

Despite speculation that natural metamers are rare,[3,4] few data have been available on their frequency. This is not surprising, since the spatial density of any particular spectral reflectance or class of reflectances in natural scenes is generally unknown. Moreover, any estimate of a spatial density must be compatible with the spatial resolution of the eye; this sets a natural limit on the extent to which spectral reflectances may be treated as unmixed. If two surfaces with different spectral reflectances cannot be spatially resolved, they are visually interchangeable with a single surface whose spectral reflectance is a mean of the two.



Two metameric surfaces from a natural scene. The surface spectral reflectances at points 1 and 2 in the scene are different but, when illuminated by skylight, produce the same patterns of excitations in the cone receptors of the eye.

We undertook a numerical evaluation of the visual discriminability of 150,000 different surfaces under different phases of daylight.[5] Using a high-resolution hyperspectral imaging system, we obtained spectral-reflectance data from 50 natural vegetated and non-vegetated scenes representing the main land-cover classifications. The frequency of metamers in each scene was estimated by the number of pairs of surfaces for which color differences were below a threshold value under one phase of daylight and above a multiple of this threshold value under another phase.

The relative frequency of metameric pairs, expressed as a proportion of all the pairs of surfaces from a scene, was found to be very low, from about 10^{-6} to 10^{-4} for the largest illuminant change tested, from skylight of correlated color temperature 25,000 K to direct sun and skylight of correlated color temperature 4000 K. Therefore, metamers are rare in natural scenes.

There is, however, another way to interpret the data—as a conditional relative frequency. When expressed as a proportion of just those pairs of surfaces that were indistinguishable under one of the phases of daylight, the relative frequency of metameric pairs was much higher, from about 10^{-2} to 10^{-1}. In this special sense, metamers are relatively common, implying that visual identity may not always be a reliable guide to material identity in natural scenes. ◭

[David H. Foster (d.h.foster@manchester.ac.uk) and Kinjiro Amano are with the School of Electrical and Electronic Engineering, University of Manchester, United Kingdom. Sérgio M.C. Nascimento is with the department of physics, Gualtar campus, University of Minho, Braga, Portugal. Michael J. Foster is with Barts and The London, Queen Mary's School of Medicine and Dentistry, University of London, United Kingdom.]

References

1. G. Wyszecki and W.S. Stiles. *Color Science: Concepts and Methods, Quantitative Data and Formulae*, 2nd ed. (John Wiley & Sons, New York, 1982).
2. S.M.C. Nascimento et al. "Psychophysical estimates of the number of spectral-reflectance basis functions needed to reproduce natural scenes," JOSA A **22**(6), 1017-22 (2005).
3. P. Lennie. "Single units and visual cortical organization," Perception **27**, 889-935 (1998).
4. M.G.A. Thomson et al. "Spatial resolution and metamerism in coloured natural scenes," Perception **29**[1 (Supplement)], 123 (2000).
5. D. H. Foster et al. "Frequency of metamerism in natural scenes," JOSA A **23**(10), 2359-72 (2006).