Motheye antireflection patterning of nonlinear optical crystals

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The reduction of Fresnel reflection losses at the surfaces of nonlinear optical crystals is important for generation of mid-infrared radiation via second harmonic and sum-frequency generation. Typically, a nonlinear optical crystal is pumped by a high-energy laser source (e.g. ? = 2.09 ?m) on one (input) surface and emits longer wavelength, broadband tunable radiation (3–6 ?m) from the other (output) surface. In order to increase the amount of light coupled into and out of the crystal, the input and output surfaces are usually treated with dielectric antireflection (AR) coatings, but these may fail under high-power conditions due to thermal mismatch, surface contamination, delamination effects under thermal cycling, and absorption at the coating-crystal interface.

An alternative AR coating, which we have demonstrated for the nonlinear zinc germanium phosphide (ZGP) material, is integrated directly into the surface by using a sub-wavelength surface relief pattern, known as a "motheye" [1]. This motheye pattern provides an index match between air and the crystal by continuously grading the effective index of refraction. Without a discontinuity in refractive index, light incident on a motheye-patterned substrate should suffer no Fresnel reflection losses. And since the motheye pattern is defined in the crystal itself, there is no thermal or physical degradation like that associated with the use of coated dielectric films.

By using submicron holographic lithography and reactive ion etching, we have produced a motheye pattern on one surface of a ZGP crystal that improved the transmittance from 51% to 67% at ? ~ 3.9 ?m (close to the theoretical maximum for a crystal with motheye patterning on one face only). Patterning both input and output surfaces is expected to increase the transmittance to over 90%. The same approach should work for other wavelengths of interest and other nonlinear optical crystals where Fresnel losses at interfaces are a problem. Our results represent the first step towards using motheye as effective integrated AR coatings for high-power nonlinear optical crystals.

[1] S. J. Wilson and M. C. Hutley, "The optical properties of motheye antireflection surfaces", Opt. Acta **29**, 993 (1982).