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Momentum and mass in the covariant theory of light in a medium

MIKKO PARTANEN, JUKKA TULKKI, Aalto University — We have recently developed a novel covariant theory of light in a medium by considering a light wave simultaneously with the dynamics of the medium driven by the optomechanical forces between the induced dipoles and the electromagnetic field. One of the most fundamental consequences of our theory following directly from the covariance principle and the fundamental conservation laws of nature is that a light pulse having a total electromagnetic energy $\hbar\omega$ propagating in a nondispersive medium transfers a mass equal to $\delta m = (n^2 - 1)\hbar\omega/c^2$, where n is the refractive index. This mass is made of atoms, which are more dense inside the light pulse due to the optomechanical forces. The predicted photon mass drag effect leads to dissipation of photon energy and it also gives an essential contribution to the total momentum of the light wave, which becomes equal to the Minkowski momentum $p = n\hbar\omega/c$. Therefore, our theory also gives a unique resolution to the centenary Abraham-Minkowski controversy. For the experimental verification of the covariant state of light in a medium, both the total momentum and the transferred mass of the coupled state of the field and matter have to be measured.

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