

MIT GRADUATE STUDENT LUNCH SEMINAR
FEBRUARY 12, 2018

STEVEN JOHNSON

Title: Upper bounds on wave-matter interactions

Abstract: It is now widely recognized that, by taking ordinary materials and re-arranging them into complex shapes on the same scale as the wavelength of light (or other wave-propagation systems), an amazing variety of new phenomena are possible. This has been exploited to engineer new classes of optical devices, from ultra-efficient solar cells to exotic optical fibers, as well as new phenomena of interest in basic physical research. A key challenge is the enormous number of degrees of freedom available to modern nanofabrication, combined with a lack of closed-form analytical solutions in all but the most trivial geometries. Instead, one form of analytical guidance comes in the form of theoretical bounds on attainable performance, which serve as both constraints and as targets to meet, or even exceed (by circumventing the assumptions underlying the bounds). Many famous such results include the Yablonovitch limit for solar cells, the Manley-Rowe limits to nonlinear frequency conversion, and the Wiener bounds on homogenized material properties. In this talk, I will review these along with some newer bounds derived in our group: upper bounds on wave scattering, absorption, and emission. Several of the bounds are derived surprisingly simply from fundamental energy considerations: the absorbed power (a quadratic function of the fields) is bounded above by the total absorbed+scattered power (the real part of a linear function of the fields via the optical theorem), and the resulting quadratic < linear constraint implies an upper bound on the material polarization. For materials with a (local, linear) susceptibility χ at a frequency ω , the resulting upper bounds on light-matter interaction depend on $|\chi|/\omega$, $\text{Im}\chi$ and the source/matter separation distance d , but are independent of shape.