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# Analysis and PDE Seminar

**Professor Robert V. Kohn**

Courant Institute of Mathematical Sciences, New York University

TITLE: Some unconventional PDE problems from photonics

*Date* : June 13th, 2025 (Friday)

*Time* : 10am-11am (Hong Kong time)

11am-12noon (Korea time)



*Link to ZOOM* : <https://cuhk.zoom.us/j/99008163597>

Meeting ID : 990 0816 3597

Password : 219834

**Abstract.** Electromagnetic waves are described by Maxwell's equations. For transverse-magnetic waves in a time-harmonic setting, the Maxwell system reduces to the divergence-form Helmholtz equation  $\operatorname{div}\left(\frac{1}{\epsilon(x,\omega)}\nabla u\right) + \omega^2\mu(x,\omega)u = 0$ , where  $u$  is scalar valued,  $\epsilon$  and  $\mu$  are the dielectric permittivity and magnetic permeability of the medium, and  $\omega$  is the frequency. One might think that we have, by now, a full understanding of the mathematical issues raised by this equation – but in fact it isn't so. Indeed, due to the frequency-dependence of the permittivity, there are materials for which  $\epsilon$  is near zero or even negative at frequencies of practical interest. The analysis of devices made by combining such materials with “ordinary” dielectrics (for which  $\epsilon$  is positive) raise numerous PDE issues that are still not well understood.

After briefly discussing a few challenges of this type I will focus mainly on a particular thread, involving the design of “geometry-invariant resonant cavities” using epsilon-near-zero materials. The basic idea was introduced by Liberal, Mahmoud, and Engheta in a 2016 Nature Communications article, where they used numerical simulation to confirm its feasibility and to study the device's sensitivity to loss. I'll discuss recent work with Raghavendra Venkatraman, which (i) explains what is happening from a PDE perspective, and (ii) studies the optimal design problem of minimizing the device's sensitivity to loss.

*All are welcome*

This is a joint activity organized by Department of Mathematics, The Chinese University of Hong Kong, Hong Kong; Department of Mathematics, Institute of Mathematical Research, Research Division of Mathematical and Statistical Science, The University of Hong Kong, Hong Kong; and Department of Mathematical Sciences, Ulsan National Institute of Science and Technology, Korea. More details can be found in [https://hkumath.hku.hk/~imr/event/CUHK\\_HKU\\_UNIST\\_Analysis\\_and\\_PDE/index.php](https://hkumath.hku.hk/~imr/event/CUHK_HKU_UNIST_Analysis_and_PDE/index.php).

