Quantum Optics

	Quantum Mechanics I	Quantum Electrodynamics (Quantum Field theory)
Matter	Quantum, non-relativistic	quantum, relativistic
Light	classical + photons	quantum

→ **Quantum Optics**

I. Quantum description of light

II. Light - Matter interactions

III. Applications (2 lectures delivered by Farid Khalili)

Books: Gerry, Knight "Introductory Quantum Optics"

Scully, Zubairy "Quantum Optics"

I. Quantum description of light

1. Quantization of E-M field

Maxwell equations (no sources)

$$\vec{\nabla}\vec{E}=0 \qquad \vec{\nabla}\times\vec{B}=\frac{1}{c^2}\dot{\vec{E}} \Rightarrow \vec{\nabla}\times\dot{\vec{B}}=\frac{1}{c^2}\ddot{\vec{E}}$$

$$\vec{\nabla}\vec{B}=0 \qquad \vec{\nabla}\times\vec{E}=-\dot{\vec{B}}$$

$$\vec{\nabla}\times(\vec{\nabla}\times\vec{E}) \quad \frac{1}{c^2}\ddot{\vec{E}}=0 \Rightarrow \vec{\nabla}^2\vec{E}-\frac{1}{c^2}\ddot{\vec{E}}=0$$

$\vec{\nabla}\times(\vec{\nabla}\times\vec{E})$ = $\vec{\nabla}(\vec{\nabla}\vec{E}) - \vec{\nabla}^2\vec{E}$, with $\vec{\nabla}\vec{E}=0$

$$\Box\vec{E}=0 \qquad \text{wave eq.} + \vec{\nabla}\vec{E}=0$$

$$\vec{E}(\vec{r},t)=\sum_{\vec{k},\sigma=1,2}\vec{e}_{\vec{k},\sigma}\,A_{\vec{k},\sigma}\,e^{i(\vec{k}\vec{r}-\omega_k t)}+c.c$$

$\omega_k = c\cdot|\vec{k}|$

$\vec{\nabla}\vec{E}=0 \Rightarrow \vec{k}\cdot\vec{e}_{\vec{k},\sigma}=0$, $\vec{e}_{\vec{k},1}\cdot\vec{e}_{\vec{k},2}=0$

$$\vec{B}(\vec{r},t)=\sum_{\vec{k},\sigma=1,2}\frac{1}{\omega_k}\vec{k}\times\vec{e}_{\vec{k},\sigma}\,e^{i(\vec{k}\vec{r}-\omega_k t)}+c.c$$