Lecture 25

Conflicting NLO definitions

High-field interactions

Guest Lecture.

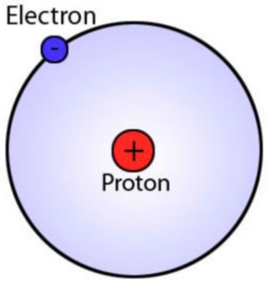
Conflicting definitions in NLO

	This Course		Other	
E-field	$E(t) = \frac{1}{2}\left(Ee^{i\omega t} + e^{-i\omega t}\right) = E\cos(\omega t)$	(Stegeman, *Nonlinear Optics*) (Boyd, *Nonlinear Optics*) (Powers, Haus, *Fundam. of Nonlin. Optics*) (Agrawal, *Nonlinear Fiber Optics*) (Demtröder, *Laser Spectroscopy*)	$E(t) = Ee^{i\omega t} + Ee^{-i\omega t} = 2E\cos(\omega t)$	(Boyd, *Nonlinear Optics*) here the Fourier component E is ½ of the field amplitude
Field propagation	$E \sim e^{i\omega t - ikz}$	(Saleh, Teich, *Fundamentals of Photonics*) (Weiner, *Ultrafast Optics)* *(Yariv, Quantum Electronics)* *(Keller,* Ultrafast Lasers	$E \sim e^{ikz - i\omega t}$	(Stegeman, *Nonlinear Optics*) (Boyd, *Nonlinear Optics*) (Powers, Haus, *Fundam. of Nonlinear Optics*) (Agrawal, *Nonlinear Fiber Optics)*
Fourier transform	$\tilde{f}(\omega) = \mathcal{F}\{f(t)\} = \int_{-\infty}^{\infty} f(t)\, e^{-i\omega t}\, dt$ $f(t) = \mathcal{F}^{-1}\{\tilde{f}(\omega)\} = \frac{1}{2\pi}\int_{-\infty}^{\infty} \tilde{f}(\omega)\, e^{i\omega t}\, d\omega$	(Weiner, Ultrafast Optics) (Keller, Ultrafast Lasers	$\tilde{f}(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} f(t)\, e^{-i\omega t}\, d\omega$ $f(t) = \int_{-\infty}^{\infty} \tilde{f}(\omega)\, e^{i\omega t}\, d\omega$	
Nonlinear Schrödinger eq.	$\frac{\partial a}{\partial z} - \frac{i}{2}\beta_2 \frac{\partial^2 a}{\partial \tau^2} + i\gamma\lvert a\rvert^2 a = 0$	Weiner, Ultrafast Optics Keller, Ultrafast Lasers	$\frac{\partial a}{\partial z} + \frac{i}{2}\beta_2 \frac{\partial^2 a}{\partial \tau^2} - i\gamma\lvert a\rvert^2 a = 0$	(Stegeman, *Nonlinear Optics*) (Boyd, *Nonlinear Optics*) (Agrawal, *Nonlinear Fiber Optics)*
Nonlinear polarization	$\mathcal{P}(t) = \epsilon_0(\ \chi^{(1)}E(t) + \chi^{(2)}E(t)^2 + \chi^{(3)}E(t)^3 + \ldots\ )$	(Stegeman, *Nonlinear Optics*) (Boyd, *Nonlinear Optics*) (Powers, Haus, *Fundam. of Nonlinear Optics*) (Agrawal, *Nonlinear Fiber Optics)* (Demtröder, *Laser Spectroscopy)*	$\mathcal{P}(t) = \epsilon_0\chi^{(1)}E(t) + 2dE(t)^2 + 4\chi^{(3)}E(t)^3 + ..$	(Saleh, Teich, *Fundamentals of Photonics*) (Yariv, *Quantum Electronics*)
Nonlinear ref. index	$n(I) = n_0 + n_2 I$	(Stegeman, *Nonlinear Optics*) (Boyd, *Nonlinear Optics*) (Powers, Haus, *Fundam. of Nonlinear Optics*)	$n(I) = n_0 + n_2\lvert E\rvert 2$	(Agrawal, *Nonlinear Fiber Optics)*

What is “strong” field from the viewpoint of nonlinear optics?

$$\mathcal{P}(t) = \epsilon_0(\chi^{(1)}E(t) + \chi^{(2)}E(t)^2 + \chi^{(3)}E(t)^3 + \ldots)$$

- this power series in electric field amplitude converges only for not large enough fields $E(t)$



What is “strong” ?

1) When optical $E(t)$ becomes comparable to the characteristic atomic electric field strength

Take Bohr atom: $E_{at} = \dfrac{e}{4\pi\epsilon_0 r_B^2} \rightarrow$ **5×10^{11} V/m**

1.6e-19/4/pi/8.85e-12/5.3e-11^2=5.1e11

Bohr radius $r_B = 5.3\times10^{-11}$ m

2) When $\chi^{(1)}E(t) \sim \chi^{(2)}E(t)^2 \rightarrow E(t) \sim \dfrac{\chi^{(1)}}{\chi^{(2)}} \sim$ **5×10^{11} V/m**

~ 1

~ 2 pm/V

$\chi^{(2)}E(t)^2 \sim \chi^{(3)}E(t)^3$ etc....

3) What laser intensity (in vacuum) this corresponds to?

$$I_L = \frac{1}{2}\epsilon_0 c E^2 = \frac{1}{2}\frac{E^2}{\eta_0} = 3.3\times10^{20}\ \text{W/m}^2 = 3.3\times10^{16}\ \text{W/cm}^2$$

377 Ohm – free space impedance $\eta_0 = \sqrt{\frac{\mu}{\epsilon_0}}$

A table-top laser setup with 1-mJ pulse energy, 30-fs duration, focused to 10-μm spot gives you **$I_L = 3.3\times10^{16}$ W/cm²**

And this is far beyong the approximation of ‘usual’ nonlinear optics