Self Phase Modulation → Closely related to Kerr nonlinearity

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$n = n_0 + n_2 I(t)$ ← look at RP Photonics for a good review

Self-phase modulation is the CHANGE in the phase of an optical pulse as it passes through a material medium as a result of nonlinearity

nonlinearity ($\tilde{A}(z,t)$ is the amplitude of the pulse)

$$I(t) = \frac{n_0 c}{2\pi} |\tilde{A}(z,t)|^2$$

From Wikipedia: Consider the NLS with no dispersion:

$$\frac{dA(z)}{dz} = -j\gamma |A|^2 A$$

Kerr effect

Nonlinear coefficient

The power of the electric field changes with distance as

$$\frac{d|A(z)|^2}{dz} = A^* \frac{dA}{dz} + A\frac{dA^*}{dz}$$

$$A = |A|e^{i\phi z},\quad A^* = |A|e^{-i\phi z}$$

$$\therefore \frac{d|A(z)|^2}{dz} = |A|e^{-i\phi z}(i\phi)|A|e^{i\phi z} + |A|e^{i\phi z}(-i\phi)|A|e^{-i\phi z}$$

$$= 0.$$

∴ The power does NOT change during propagation

⇒ The nonlinearity can only cause a phase rotation.

Using $A = |A|e^{j\phi}$ in the NLS with no dispersion:

$$\frac{d|A|e^{j\phi}}{dz} = \frac{d|A|}{dz}e^{j\phi} + j|A|e^{j\phi}\frac{d\phi}{dz} = -j\gamma |A(z)|^3 e^{j\phi}$$

$$\Rightarrow \underbrace{\frac{d|A|}{dz}}_{=0} + j|A|\frac{d\phi}{dz} = -j\gamma |A(z)|^3$$

$$\therefore \frac{d\phi}{dz} = -\gamma |A|^2$$

$$\therefore \phi(z) = \phi(0) \underbrace{- \gamma |A(0)|^2 z}_{\text{SPM}}$$