PHYS 523 – Nonlinear Optics
HW #1, January 7 2005

Due Monday, January 31, 2005

1. A portion of your Ph.D. thesis requires a high power (~ 100 mW) coherent light source at 392 nm with a relatively narrow linewidth (~ 100 MHz). These requirements cannot be satisfied by a commercial product, so you will have to build such a source. Smile...such is the fun and carefree life of a graduate student.

a) One possible solution is to simply frequency double a widely available 784 nm laser (laser diode, Ti:Sapphire laser, etc). Using an appropriate nonlinear crystal (LBO, BBO, or ?) and length to give you the highest conversion efficiency, estimate amount of generated 392 nm light using both the depleted and nondepleted approximation in a single pass configuration. What type of phase matching did you use? You should find the power requirements of the 784 nm source are (practically) too large to realize 100 mW at 392 nm.

b) As you found in part a), the shortcoming is a lack of optical power at the fundamental wavelength. But all is not lost. One possibility is to use a high-finesse build-up cavity. After such a cavity is "charged" up, a much higher (fundamental) optical power is circulating within the cavity. Next, by placing a nonlinear crystal inside the cavity, a higher conversion to the second harmonic can be realized. So in this problem, the task is to design such a cavity and estimate the power gain of the second harmonic field. You should design a bow tie (ring) cavity instead of a standing wave (linear) cavity in order to optimize the SHG in a single mode. In your solution, you should include all relevant information, such that if you came back to your solution in 6 months, you could begin to build your designed cavity in the lab. For example, you should specify the input and output polarizations, the phase matching angles and/or temperatures, the cut of the crystal, the cavity parameters,

Some points to keep in mind as you work through this problem

- You will want to maximize the fundamental intensity at the nonlinear crystal, which means a minimum spot size on the crystal. However, the cavity must support a stable (spatial) Gaussian mode.
- You should consider reflections at the crystal interfaces. What are the consequences of any reflections on SHG. Is there a way to circumvent this complication?
- The analysis of the finesse of the cavity will need to include the "loss" of the fundamental to SHG.

Answer the following Bonus questions only after you have completed the preceeding parts.

- In order for the buildup cavity to have coherent addition, its length must be stabilized so that it remains resonant with the fundamental wavelength. In your design, you should include a description of your feedback stabilization scheme to achieve this length stabilization.

- For this bow-tie configuration, why and how should you design your cavity to eliminate the astigmatism of the fundamental beam?

Suggested reading: (see provided links)

- SHG references:
  Mills pages 51-63
  G.D. Boyd and D.A. Kleinman, J. Appl. Phys. **39**, 3597 (1968)
- Examples of Resonant SHG Cavities:
  A. Ashkin, G. D. Boyd, and J. M. Dziedzic, IEEE J. Quant. Electronics **2**, 109 (1966)*
  W. J. Kozlovsky, C.D. Nabors, and R. L. Byers, IEEE J. Quant. Electronics **24**, 913 (1988)*
  Kaler et al, Phys Rev A **51**, 2789 (1995)
  Hemmerich et al Opt Lett. **15**, 372 (1990)
- Cavity Stability of Gaussian modes:
  Saleh and Teich Fundamentals of Photonics ISBN 0-471-83965-5 (on reserve)
  Yariv Chapter 7
- Nonlinear crystals:
  Yariv and Yeh, Optical Waves in Crystals ISBN 0-471-43081-1 (on reserve)
- Stabilization schemes:
  T. W. Haensch and B. Couillau, Opt. Commun. **35**, 441 (1980)

* these papers will be reviewed in class the week of January 17.