PHSX 331 HW 7. (DATE) - Laser Threshold

Question 1

A solid state laser is a collection of special atoms that we'll call "laser active ". These are arranged in a solid state matrix between two reflective mirrors. A source of energy (pump) excites the atoms out of the ground state. These excited atoms will release their energy as a photon, and drop back down to the ground state. If the pump is weak, then the laser will act like a lamp, each atom oscillates independently and emits a random photon of light. Once the pump reaches a certain threshold then the atoms will oscillate in phase and the lamp becomes a laser. The number of photons $n(t)$ has a rate of change given by,

$$\frac{dn}{dt} = \text{gain} - \text{loss} \tag{1}$$

$$= GnN - kn \tag{2}$$

$N(t)$ is the number of exited atoms, G is the gain coefficient, k is a constant so that $1/k$ is the expected lifetime of a photon. When an excited atom emits a photon it drops back down to the ground state, so we can write the number of atoms in excited states can be written as,

$$N(t) = N_0 - \alpha n \tag{3}$$

N_0 is the number of excited atoms the pump can keep excited, α is the decay rate, then the differential equation for the number of photons is,

$$\frac{dn}{dt} = (GN_0 - k)n - (\alpha G)n^2 \tag{4}$$

For all parts use $G = 5$, $\alpha = 3$, $k = 30$.

- What are the units of G, N_0, k, and α?
- Write a function in Python for $\frac{dn}{dt}$.
- Use rk2_1d.py to solve for $n(t)$ with an initial condition of $n(0) = 100$. Run the program for pump strength of $N_0 = 1, 10$ and 100.
- Plot n as a function of time for each of the different pump strengths. Make sure to label and add a legend to the plot.
- Make a second plot for a pump strength of $N_0 = 1$ and an initial condition of $n(0) = 0,\ 10^2,$ and 10^4 photons. How does the initial condition affect the final state of the laser.
- Make a third plot with a pump strength of $N_0 = 10$ with initial conditions $n(0) = 0,\ 10^2,$ and 10^4 photons. How does the initial condition affect the final state of the laser.
- Based on your graphs what matters more in making the laser, the number of photons you start with, of the strength of the pump.
- Try to find the Threshold N_0 where the atoms switch between just being a lamp, and becoming a laser.