QUANTUM ELECTRONICS AND ATOMIC PHYSICS

BASIC INSTRUCTIONS OF THE COURSE

- Instructor: Kihwan Kim 金奇奂,
  MMW-S423, kimkihwan@mail.tsinghua.edu.cn
- Teaching Assistant: Shuaining Zhang 张帅宁,
  MMW-S427, shiningpku@gmail.com
- Class hours: Tue from 9:50 am to 12:15 pm
- Class Room: MMW-S327
- Homework:
  - How often? every week
  - When to submit? in two weeks after the assignment
  - Where to submit? Online
  - Problem solving? In the end of the class after the submission

GRADING

• Midterm	20%
• Final	20%
• Homework	50%
• Attendance	10%

- Extra Points for “Good Questions” or “Good Answers” in class
  - Broad questions that the instructor cannot answer in the same class generally qualifies!
  - Answers that the instructor cannot provide in the class
  - Equivalent to the point of one week of homework

TEXT BOOKS & REFERENCES

- Quantum Electronics for Atomic Physics

by Warren Nagounary (Oxford Press 2010)

- Atomic Physics

by Foot, C. J. (Oxford University Press, 2005)

- Fundamentals of Photonics

by Saleh, B. E. A. and Teich, M. C. (2nd Ed., Wiley-Interscience, 2007)

- Lasers

by Siegman, A. E. (University Science Books, 1986)

TOPICS

1. Gaussian beams
2. Optical resonators - geometrical properties
3. Energy relations in optical cavities
4. Optical cavity as frequency discriminator
5. Laser gain and some of its consequences
6. Laser oscillation and pumping mechanisms
7. Descriptions of specific CW laser systems
8. Laser gain in a semiconductor
9. Semiconductor diode lasers
10. Mode-locked lasers and frequency metrology
11. Laser frequency stabilization and control systems
12. Atomic and molecular discriminants
13. Nonlinear optics
14. Frequency and amplitude modulation

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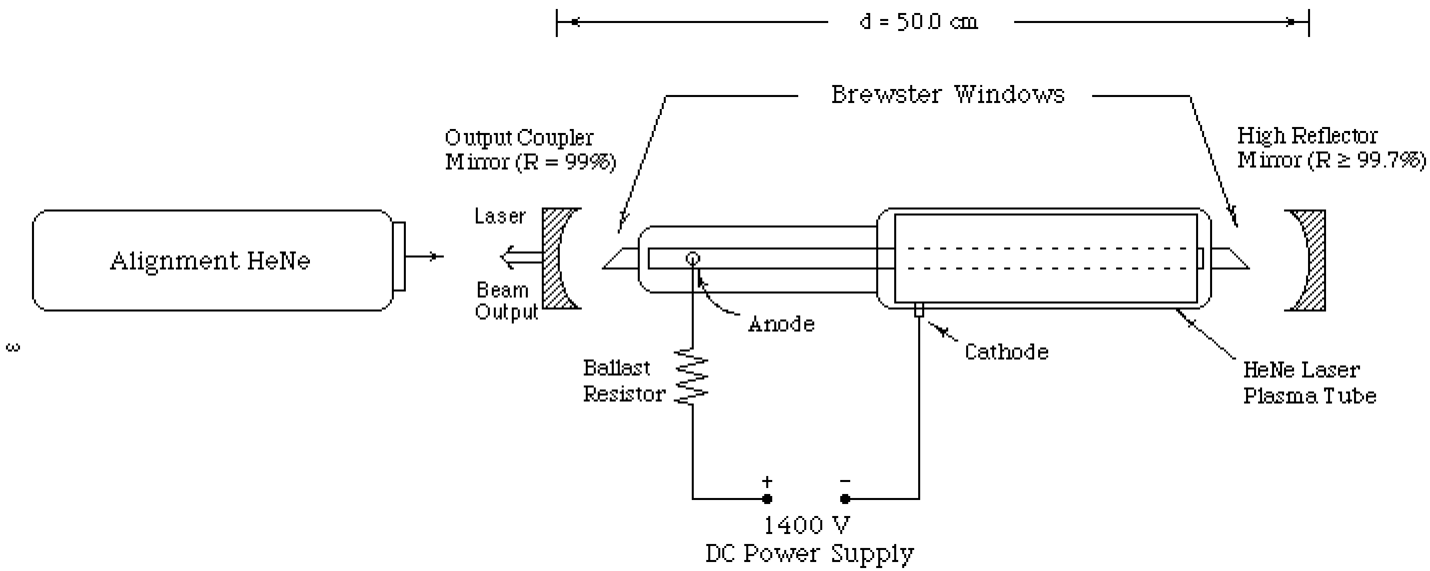


1. GAUSSIAN BEAM

1.2 PARAXIAL WAVE EQUATION

- Wave equation $$\nabla^2 u - \frac{1}{c^2}\frac{\partial^2 u}{\partial t^2} = 0,$$
- With a time dependency by $e^{i\omega t}$
$$\nabla^2 u + k^2 u = 0,$$
- With paraxial assumption that requires that the normals to the wavefronts make a small angle
$$u(x, y, z) = \psi(x, y, z)e^{-ikz}$$
- The Paraxial Wave Equation
$$\boxed{\nabla_t^2 \psi - 2ik\frac{\partial \psi}{\partial z} = 0,}$$

where $\nabla_t^2 \left(= \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right).$

1.3 GAUSSIAN BEAM FUNCTIONS AND THE COMPLEX BEAM PARAMETER

- A simple solution of the paraxial wave equation

$$\boxed{\nabla_t^2 \psi - 2ik\frac{\partial \psi}{\partial z} = 0,}$$

- A trial solution,

$$\psi(x, y, z) = \exp\left\{-i\left(P(z) + \frac{k}{2q(z)}r^2\right)\right\}, \quad r^2 = x^2 + y^2,$$

$$\frac{dq(z)}{dz} = 1 \quad \text{and} \quad \frac{dP(z)}{dz} = -\frac{i}{q(z)}$$

Homework #1: derive the above equations

$$\psi(x,y,z) = \exp\left\{-i\left(P(z) + \frac{k}{2q(z)}r^2\right)\right\}, \quad r^2 = x^2 + y^2,$$

$$\frac{dq(z)}{dz} = 1 \quad \text{and} \quad \frac{dP(z)}{dz} = -\frac{i}{q(z)}$$

$$q(z_2) = q(z_1) + (z_2 - z_1)$$

$$\frac{1}{q} = \frac{1}{R} - i\frac{\lambda}{n\pi\omega^2}$$, complex beam parameter q

Since, $u(x,y,z) = \psi(x,y,z)e^{-ikz}$, $k = \dfrac{n\omega}{c} = \dfrac{2\pi n}{\lambda}$

$$u(x,y,z) = \exp\left\{-i\left(P(z) + kz + k\frac{r^2}{2R}\right) - \frac{r^2}{\omega^2}\right\}$$

The radius of the beam is ω.

The wave-front would be

$$z + \frac{r^2}{2R} = const.$$

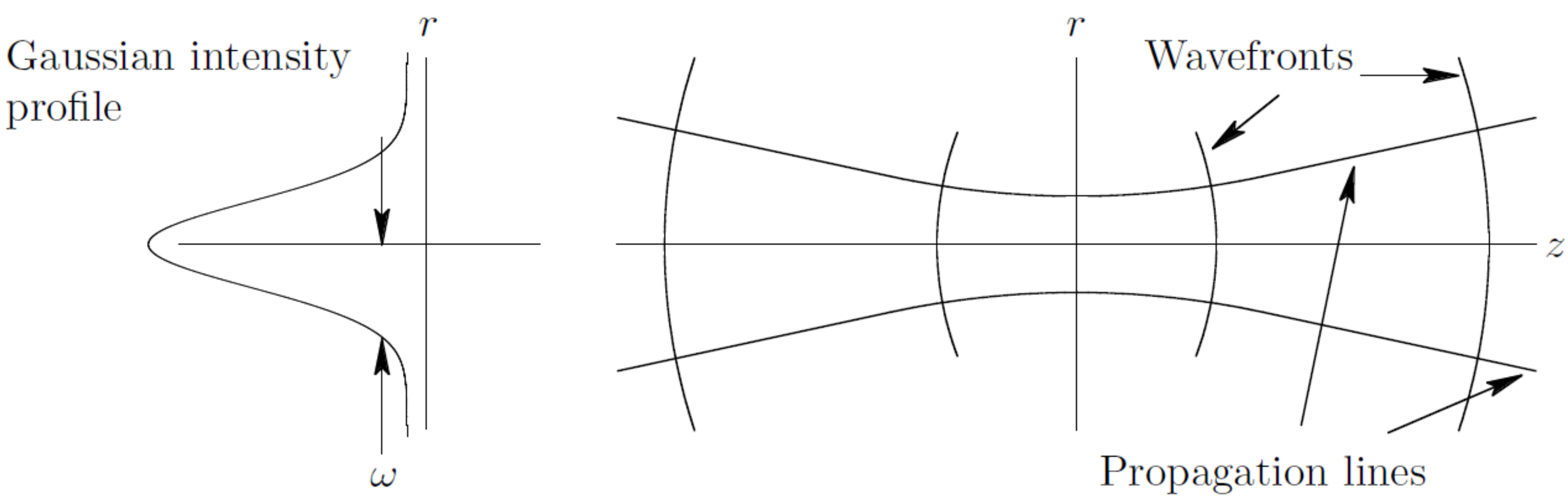
$$\frac{1}{q} = \frac{1}{R} - i\frac{\lambda}{n\pi\omega^2} \qquad u(x,y,z) = \exp\left\{-i\left(P(z) + kz + k\frac{r^2}{2R}\right) - \frac{r^2}{\omega^2}\right\}$$

The wave-front would be

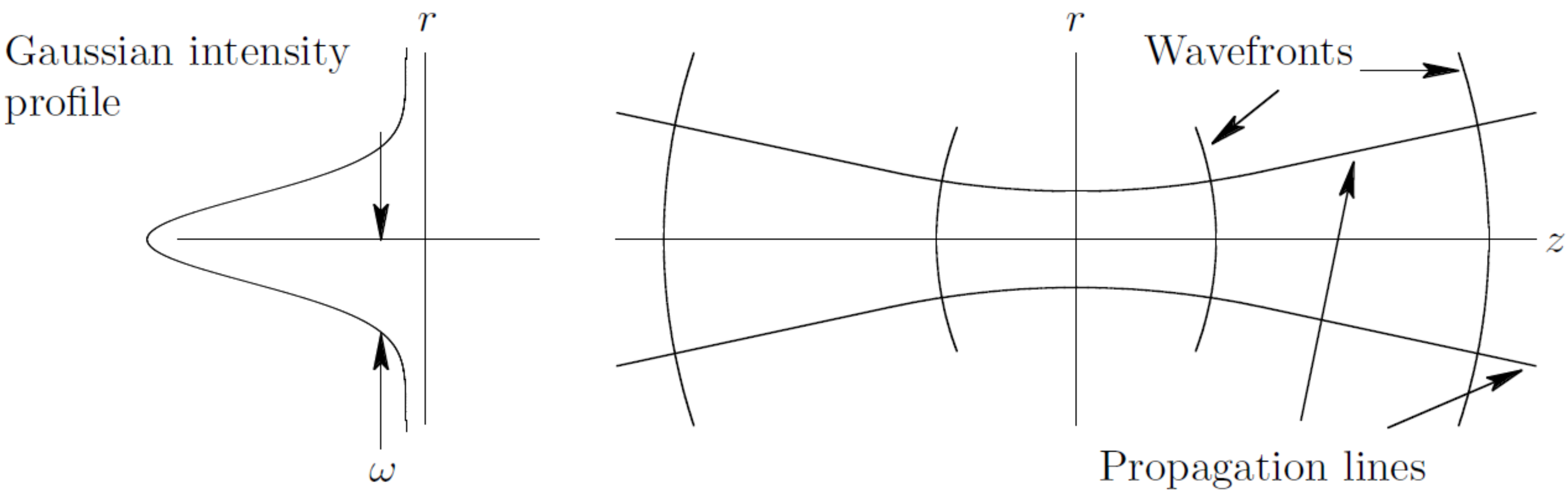
$$z + \frac{r^2}{2R} = const$$

The radius of the beam is ω.

When $r \ll R$, the paraxial approximation, R can be considered as the radius of a wave-front sphere

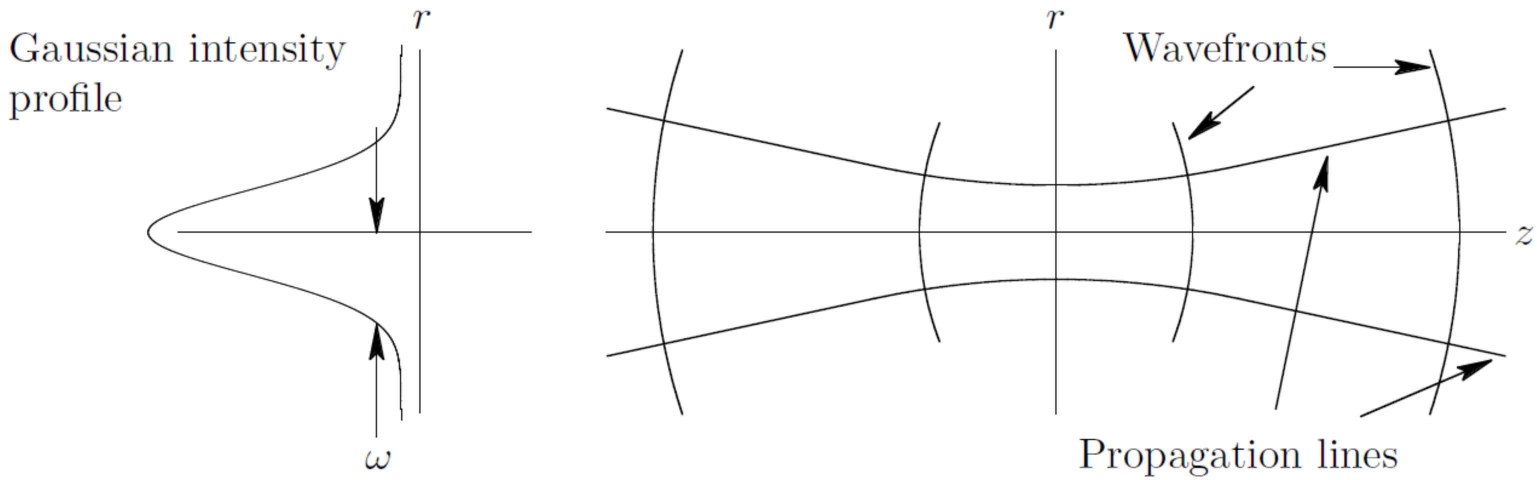


1.4 SOME GAUSSIAN BEAM PROPERTIES



$$\text{At waist:} \quad q \equiv q_0 = i\frac{n\pi\omega_0^2}{\lambda} \qquad \frac{1}{q} = \frac{1}{R} - i\frac{\lambda}{n\pi\omega^2}$$

$$q(z) = q_0 + z = i\frac{n\pi\omega_0^2}{\lambda} + z \qquad q(z_2) = q(z_1) + (z_2 - z_1)$$



$$q(z) = q_0 + z = i\frac{n\pi\omega_0^2}{\lambda} + z \qquad \frac{1}{q} = \frac{1}{R} - i\frac{\lambda}{n\pi\omega^2}$$

$$\text{Distance to waist } = -Re\{q(z)\} \quad \text{and,}$$

$$\text{Radius of waist } = \sqrt{\frac{\lambda}{n\pi} Im\{q(z)\}}.$$

$$\omega(z) = \omega_0 \left[1 + \left(\frac{\lambda z}{n\pi\omega_0^2}\right)^2\right]^{1/2}$$

$$R(z) = z\left[1 + \left(\frac{n\pi\omega_0^2}{\lambda z}\right)^2\right].$$

Homework #2: derive the above equations and draw the functions