Name: Date:

Exam: Physical Optics Summer Semester 2021/22. Good Luck!

Task 1: Coherence and Michelson Interferometer (6 Points)

a) What is Coherence? (1 Point)
b) With what device can we measure temporal, and with what spatial coherence? (1 Point)
c) Suppose you have a Michelson interferometer consisting of a 50:50 beam splitter (intensity is equally split into the two arms) and both mirrors have reflectivity of 96%. The input is a laser beam with intensity of I_0 = 1 W/m^2 and wavelength of 532 nm.
What is the contrast/visibility that can be achieved with such an interferometer? (1 Point)
d) What is the maximum and what the minimum achievable intensity at the output of the interferometer? (2 Points)
e) Suppose the mirrors are at positions so that intensity at the output is at its minimum. By how much would you have to move one of the mirrors, so that the output intensity would reach its maximum? (1 Point)

Task 2: Fresnel Formalism (5 Points)

a) Consider a ray that travels through air and hits the surface of a lake under a certain angle *i* (water is perfectly calm, therefore flat). Refractive index of air is n_a = 1 and water n_w = 1.33. The incident angle *i* is such that one of the two principal polarization components is completely transmitted. Which component is that, s or p? What is that special angle called? (2 Points)
b) Calculate the angle *i*. (1 Point)
c) Calculate what fraction of the input intensity is reflected. (2 Points)

Task 3: Photon Statistics and non-linear Optics (5 Points)

a) A 633 nm laser light is incident on a fast photodiode detector with a 1 ns exposure time. A stack of filters attenuates the initial laser power by a factor of 10^{-10}, such that for each exposure, the average number of photons that reach the detector is 0.1. What is the chance that at least one photon hits the detector within a single exposure interval? (1 Point)
b) What is the initial laser power? (2 Points)
c) Now suppose you have also a 1064 nm and a 1550 nm laser at your disposal, in addition to the 633 nm one. With what combination of the available lasers and through which nonlinear process you could, in principle, generate a 3.393 µm wavelength? Support your answer with calculation. (2 Points)

<u>Multiple Choice Questions</u>:

Please mark the correct answer – there is only one, or is there? (seriously though, there is only one). 0.5 Points for every correct answer.

1. If the magnification of a lens is dependent on the distance from the optical axis, the aberration that arises is called:
    a. Coma
    b. Astigmatism
    c. Field Curvature
    d. Distortion
    e. Chromatic Aberration

2. X is an optical defect due to which a comet-like image is formed instead of a point image. X is:
    a. Coma
    b. Astigmatism
    c. Field Curvature
    d. Distortion
    e. Chromatic Aberration

3. Which orthonormal functions are commonly used to describe and calculate wave aberration surfaces in circular coordinates:
    a. Abbe Polynomials
    b. Fresnel Polynomials
    c. Fraunhofer Polynomials
    d. Zernike Polynomials
    e. Seidel Polynomials

4. The microscopy acronym SMLM stands for
    a. Single Mirror Light Microscope
    b. Standard Microscopy with Light Modulation
    c. Single Molecule Laser Microscopy
    d. Single Molecule Localization Microscopy
    e. Stimulated Emission Depletion Microscopy

5. Which super-resolution microscopy technique makes use of a 2π rotational phase mask in order to engineer the <u>excitation</u> PSF into a doughnut shape:
    a. Total Internal Reflection Microscopy
    b. Stimulated Emission Depletion Microscopy
    c. Structured Illumination Microscopy
    d. MINFLUX Microscopy
    e. Scanning Electron Microscopy

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6. Which of the following models is ONLY valid under the assumption of small angles within the optical system:
   a. Rigorous Waveoptic
   b. Vectorial Waveoptic
   c. Scalar Waveoptic
   d. Paraxial Waveoptic
   e. Geometrical Optic

7. Highlight the proper Propagation-Matrix if you want to describe a thin lens with focal length *f* in optical Matrix Calculus:

$$\underline{M}^{-1} = \begin{pmatrix} D & -B \\ -f*C & A \end{pmatrix} \qquad \underline{M} = \begin{pmatrix} 1 & L \\ f & 1 \end{pmatrix} \qquad \underline{M} = \begin{pmatrix} 1 & 0 \\ \frac{n}{f} & 1 \end{pmatrix}$$

$$\underline{M} = \begin{pmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{pmatrix} \qquad \underline{M} = \begin{pmatrix} 1 & 0 \\ f & \frac{n}{n'} \end{pmatrix} \qquad \underline{M} = \begin{pmatrix} \frac{1}{\Gamma} & L \\ f & \Gamma \end{pmatrix}$$

8. Which surface treatment can achieve the lowest roughness combined with the best control, for optical surfaces:
   a. Grinding
   b. Polishing
   c. Ion beam Finishing
   d. Diamond Turning
   e. Plasma Etching

9. A Quarter-Waveplate:
   a. Shifts the wavelength of the incoming light by a factor of 0.25
   b. Turns linear polarized light into circular polarized light
   c. Turns elliptically polarized light into circular polarized light
   d. Rotates linear polarized light by 90 degrees
   e. Rotates linear polarized light by 45 degrees

10. A Half-Waveplate:
    a. Shifts the wavelength of the incoming light by a factor of 0.5
    b. Turns linear polarized light into circular polarized light
    c. Turns elliptically polarized light into circular polarized light
    d. Rotates linear polarized light by 90 degrees
    e. Rotates linear polarized light by 45 degrees

You probably studied a lot and most of the things you studied were completely irrelevant for this exam! <u>For up to 2 BONUS POINTS</u>, elaborate on something interesting you studied in vain for this exam or learned during the semester.