# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION
## SEMESTER II
## SESSION 2022/2023

| | | |
|---|---|---|
| COURSE NAME | : | FIBER OPTICS |
| COURSE CODE | : | BWC 33103 |
| PROGRAMME CODE | : | BWC |
| EXAMINATION DATE | : | JULY/ AUGUST 2023 |
| DURATION | : | 3 HOURS |
| INSTRUCTIONS | : | 1. ANSWER ALL QUESTIONS<br>2. THIS FINAL EXAMINATION IS CONDUCTED VIA<br>☐ Open book<br>☒ Closed book<br>3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK |

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

**Q1** (a) State the role of fiber optics in the evolution of 5G technologies.

(2 marks)

(b) Explain the impact of the performance of optical fibers in fiber optics technology in terms of data rates and distance limitations.

(6 marks)

(c) Derive the formula of the mode field diameter of an optical fiber and the significance terms of mode propagation.

(6 marks)

(d) Calculate the maximum acceptance angle if a graded-index optical fiber with a core refractive index of $n_1 = 1.52$ and a cladding refractive index of $n_2 = 1.48$.

(5 marks)

(e) A step-index optical fiber with a refractive index at the fiber core and cladding of 1.52 and 1.48, respectively at a wavelength of 1550 nm. Calculate;

(i) the refractive index change, $\Delta$.
(ii) the maximum fiber core diameter when $V \approx 2.405$.

(6 marks)

**Q2** A company plan to implement a fiber optic link to connect two buildings 10 km apart. The link will be used to transmit data at a rate of 10 Gbps. The company needs to ensure that the link has a minimum signal-to-noise ratio of 20 dB, and is designed to accommodate future upgrades to higher data rates. The company has hired you as a consultant to design the fiber optic link.

(i) Calculate the maximum attenuation the fiber optic link while maintaining a signal-to-noise ratio of 20 dB.

(6 marks)

(ii) Select an appropriate optical fiber type for the link based on the required data rate, distance, and attenuation specifications. Explain your selection.

(3 marks)

(iii) Calculate the total attenuation of the selected fiber optic cable at the operating wavelength and determine whether it meets the attenuation requirements of the link.

(5 marks)

(iv) Explain the main causes of optical attenuation in the fiber optic link, and how they can be minimized.

(6 marks)

(v) Explain the main safety precautions that should be taken when working with fiber optic cables and equipment.

(3 marks)

(vi) Describe the main tests that should be performed to verify the performance of the fiber optic link and explain their significance.

(2 marks)

**Q3** (a) You have just completed splicing 36 for core loose cable and found some cores are of high losses which as shown in **Figure Q3.1**. The faulty cores are numbers 15, 25, 30 and 35. Identify the color of the core and tube for all faulty cores and number of tubes for all faulty cores.

(16 marks)

(b) A telecommunications company plan to install an optical fiber cable to connect two buildings 5 km apart. The cable will transmit data at a rate of 10 Gbps. The company requires the cable to have a minimum bandwidth of 2 GHz·km and a minimum tensile strength of 1000 N. **Figure Q3.2** shows the datasheets of two types (SMF-28-100 and DCF4) of optical fiber from an international manufacturer. By referring to its datasheet, choose a suitable type of optical fiber cable for this application, and explain your selection (hint: calculate the dispersion of the fiber cable).

(9 marks)

**Q4** (a) Explain **TWO (2)** main advantages and disadvantages of direct detection and coherent detection in optical fiber communication systems.

(4 marks)

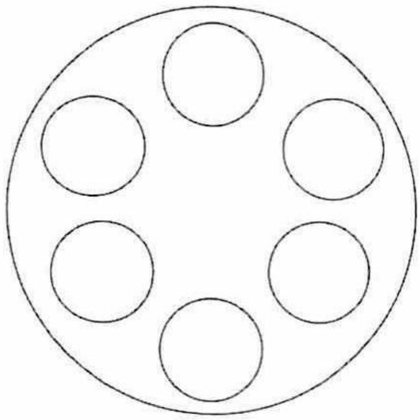
(b) A company is required to design an optical fiber communication system using a laser diode that operates at a wavelength of 1550 nm. Two laser diodes with different spectral widths, namely 2 nm and 10 nm, are available to the company. Analyze the influence of spectral width on system performance and suggest the appropriate laser diode for the given application.

(11 marks)

(b) A company is designing an optical fiber communication system that requires a photodetector to operate at a wavelength of 1310 nm. The company has two options of photodetectors with different responsivities: 0.6 A/W and 1 A/W. Discuss the impact of the responsivity on the system sensitivity, and recommend a suitable photodetector for this application.

(10 marks)

– **END OF QUESTIONS** –



| Tube No. / Tube Color | Core No. / Core Color |
|---|---|
| | |
| | |
| | |
| | |
| | |

**Figure Q3.1**

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THORLABS

## Single Mode Fiber with Ø900 µm Hytrel Jacket

SMF-28-100

### *Description*

Thorlabs' single mode SMF-28-100 fiber jacketed with Ø900 µm yellow Hytrel tubing delivers high performance across a broad spectral range in the telecom region, and also features exceptional core / clad concentricity specifications.

### *Specifications*

| Geometrical & Mechanical | |
|---|---|
| Core Diameter | 8.2 µm |
| Cladding Diameter | 125 ± 0.7 µm |
| Coating Diameter | 242 ± 5 µm |
| Core-Clad Concentricity | ≤0.5 µm |
| Coating-Clad Concentricity | <12 µm |
| Fiber Curl | ≥4.0 m Radius of Curvature |
| Operating Temperature | -60 to 85 °C |
| Proof Test Level (245 coat) | ≥100 kpsi (0.7 GN/m²) |
| Fiber Length | 100 m |
| Jacket | Ø900 µm Hytrel |

| Optical | |
|---|---|
| Numerical Aperture (nominal) | 0.14 |
| Attenuation* | ≤0.32 dB/km @ 1310 nm<br>≤0.32 dB/km @ 1383 nm**<br>≤0.21 dB/km @ 1490 nm<br>≤0.18 dB/km @ 1550 nm<br>≤0.20 dB/km @ 1625 nm |
| Operating Wavelength | 1260 - 1625 nm |
| Mode Field Diameter | 9.2 ± 0.4 µm @ 1310 nm<br>10.4 ± 0.5 µm @ 1550 nm |
| Dispersion | ≤18.0 ps/(nm·km) @ 1550 nm<br>≤22.0 ps/(nm·km) @ 1625 nm |
| Polarization Mode Dispersion, Link Design Value | ≤0.04 ps/√km |
| Polarization Mode Dispersion, Maximum Individual Fiber | ≤0.1 ps/√km |
| Bend Loss for 100 Turns on 25 mm Mandrel | ≤0.01 dB @ 1550 nm |

*Maximum specified attenuation value available within the stated ranges.
** Attenuation values at this wavelength represent post-hydrogen aging performance.

Specifications Subject to Change without Notice

November 24, 2015
2290-S01, Rev H
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**Figure Q3.2 SMF-28-100**

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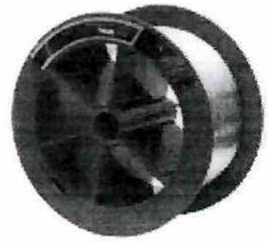
## Non-Zero Dispersion-Shifted Fiber



DCF4

### Description

Thorlabs' DCF4 Non-Zero Dispersion-Shifted Fiber (NZ-DSF) is designed to operate over the entire C-band. Because of its low dispersion, short-to-medium lengths of DCF4 fiber minimize the dispersion added to the system. For low-dispersion systems, the dispersion from DCF4 can be compensated using short lengths of other fibers that have positive dispersion, such as SMF-28 Ultra. Additionally, DCF4 fiber has a large effective area that allows the fiber to carry high optical power without significant non-linear effects.

### Specifications

| Dispersion Specifications[a] | |
|---|---|
| Dispersion @ 1550 nm | -4.0 ps/nm•km |
| Dispersion Slope @ 1550 nm | 0.12 ps/nm²•km |
| Polarization Mode Dispersion | ≤0.1 ps/√km |

a. These represent typical values.

| General Specifications | |
|---|---|
| Operating Wavelength | 1530 - 1565 nm (C-Band) |
| Mode Field Diameter @ 1550 nm | 8.85 to 9.60 µm |
| Effective Area @ 1550 nm | 65 µm² |
| Cladding Diameter | 125.0 ± 1.0 µm |
| Coating Diameter | 250 ± 5 µm |
| Coating-Cladding Concentricity | <12 µm |
| Core-Clad Concentricity | ≤0.5 µm |
| Cutoff Wavelength | ≤1500 nm |
| Attenuation @ 1550 nm | ≤0.210 dB/km |
| Point Discontinuity @ 1550 nm | ≤0.05 dB |
| Optical Return Loss | ≥60 dB |

June 13, 2018
TTN160391-S01, Rev A
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Figure Q3.2 DCF4