McGill
Faculty of Engineering

Course Outline
ECSE 430/540 (Crosslisted)

Course Title: Photonic Devices and Systems (ECSE 430)
Photonic Devices and Applications (ECSE 540)

Credits: 3

Contact Hours: (ECSE 430: 3-2-4; ECSE 530: 3-0-6) on average each week for 13 weeks: three hours of lectures, two hours of tutorials (ECSE 430 only), and four hours of individual work (six hours for ECSE 540). Total of 135 hours for the semester.

Course Prerequisite(s): ECSE 352 (EM Waves) or ECSE 354 (EM Wave Propagation)
MIME 262 (Properties of Materials in Electrical Engineering)

Course Description: ECSE 430: Introduction to photonic devices and applications. Semiconductor lasers, optical amplifiers, optical modulators, photodetectors and optical receivers, optical fibers and waveguides, fiber and waveguide devices. Photonic systems (communications, sensing, biomedical). Experiments on characterizing photonic devices and systems. Optical test-and-measurement instrumentation.
ECSE 540: Physical basis of passive and active photonic devices, including optical waveguides and fibers, semiconductor lasers, photodetectors, modulators, and amplifiers. Applications to optical signal processing and photonic systems. Introduction to optical test-and-measurement instrumentation.

Instructors: Prof. Odile Liboiron-Ladouceur and Dr. Kaveh Mojaver
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Office hour: Tuesdays 9-10 am

Lectures:	TR	1:05 – 2:25 PM	Zoom via MyCourses (recorded)
Tutorial:	F	12:35 – 2:25 PM	Zoom via MyCourses (recorded)

Teaching assistant Md Masnad Mahadi (md.masnad@mail.mcgill.ca)
office hour: by appointment

Course Website: https://mycourses2.mcgill.ca
All class material will be distributed online. Please check MyCourses regularly for announcements.

Evaluation:	Four Assignments	30%
	Two Midterms (open-book, take-home)	30%
	Research Paper	20%
	ECSE 540: In-class presentation	20%
	ECSE 430: online quizzes and peer evaluation	20%

Practice problems can be found in the assigned textbook, although not provided nor graded towards final grade. It is at the student discretion to do them in preparation for the assignments and midterms.

There will be four assignments which will count for 30% of the final grades. The assignments will be due two weeks after being posted on MyCourse. Assignments are to be submitted through MyCourse and will be graded by the TA. Students are encouraged to work together on those assignments while following academic integrity policies.

There will be two open-book, take-home midterms. One will be in the week before the spring break while the other one will be before the presentations at the end of the semester. The two midterms account for 30% of the final grade. Students will be given 24 hr to complete the midterms. Students must work individually on the midterms. Any signs of plagiarism or academic misconduct (see below *Academic Integrity*) will be reported to the Faculty of Engineering.

The students will be teamed up for the research paper (20% of the final grade). Each team will include one student registered in ECSE-540 and two to three students registered in ECSE-430. Details related to the research paper will be provided in a separate document. Students registered in ECSE-540 will be presenting on the research paper (20% of the final grade).

Students registered to ECSE-430 will have online quizzes to be completed on the library seminar and technical seminars presented during the tutorial sessions. The five best quiz grades will account for 10% of the final grade. The 430 students will also evaluation the in-class presentations at the end of the semester. This peer evaluation accounts for 10% of the final grade.

Learning Outcomes (LO): The purpose of this course is to provide the student with a fundamental understanding of passive and active photonic devices. The student should then have the necessary background to take 'follow-up' graduate courses in photonics, e.g., ECSE 515 Fiber Optical Communications, ECSE 527 Optical Engineering, ECSE 571 Optoelectronics Devices, ECSE 572 Nonlinear Optics, and ECSE 596 Optical Waveguides.

LO1 Understand guided modes and propagation constants; use appropriate equations, and models to determine characteristics of and/or design optical waveguides (planar and circular) that meet specific requirements
LO2 Describe the principle of operation of semiconductor laser diodes and determine their key operating parameters (e.g., threshold current and modulation bandwidth)
LO3 Use physical and empirical models to analyze or design electro-optic and electro-absorption modulators
LO4 Use appropriate metrics to compare the performance of semiconductor photodetectors
LO5 Differentiate between optical amplifier technologies and calculate fundamental quantities (e.g., gain, power conversion efficiency, noise figure)
LO6 Specify measurement processes and/or the necessary test-and-measurement instruments for characterizing optical signals

LO7 Specify operating characteristics of devices and components for different system applications

Instructional Method: This course will consists of two lectures a week, each of 70 minutes. Live lectures will be through Zoom synchronized with the scheduled lecture time. New concepts and their application will be introduced during the lectures. It is strongly recommended that students attend all lectures preferably live although the lectures will be recorded and posted on MyCourse. Students are strongly encouraged to read relevant sections of the assigned textbook.

In addition to the lectures, there will be a weekly two-hour tutorial session on Fridays. Background material will be reviewed during the tutorial sessions in the first two weeks. A mandatory library workshop is scheduled during one of the tutorial sessions on January 22. Technical seminars will be presented during the tutorial sessions in the first hour while the second hour will be dedicated to reviewing material presented in the lectures. Tutorial sessions will be recorded and posted on MyCourse.

Course Materials and Textbooks: The following textbook will be used throughout the course and is available in the Schulich Science and Engineering Library on regular loan. Relevant chapters will be made available on MyCourses in the first two weeks of the semester:
G.P. Agrawal, *Lightwave Technology: Components and Devices.* New Jersey: John Wiley & Sons, Inc., 2004. ISBN: 0-471-221573-2

Other recommended textbooks on optical devices and communications include the following ones which are available as ebooks through McGill library:

- A. Yariv and P. Yeh, *Optical Electronics in Modern Communications*, 6th edition. University Press (2006). ISBN: 978-0195179460
- C. Pollock and M. Lipson, *Integrated Photonics*. Kluwer Academic Publishers (2003). ISBN: 1-4020-7635-5
- K. Okamoto, *Fundamentals of Optical Waveguides*, 2nd edition. Academic Press (2006). ISBN: 978-0125250962
- G. Keiser, *Optical Fiber Communications,* 3rd edition, McGraw-Hill (2000)

Recommended textbook for reviewing fundamentals of semiconductor devices (ebook version are available through McGill library):

- D. A. Neamen, *Semiconductor Physics and Devices: Basic Principles*, 4th edition, McGraw-Hill (2003) ISBN: 0073529583

Live Polling: Polling will be used in this course to enhance engagement and increase interactiiony. During a live lecture on Zoom with polling questions, students can respond to questions from the instructor from a personal device (smartphone, tablet, or laptop) connected to the Internet. Polling will be available through www.mcgill.ca/polling. To participate in Polling sessions, students need first register for an account by clicking on **Register Your Account** at www.mcgill.ca/polling and logging in with your McGill username and password. Follow the prompts to agree to the terms of use and create your account. For more information, please visit the **Getting Started for Students** section at www.mcgill.ca/polling. The polling session name will be *photonics*. Prizes will be given away throughout the semester to ECSE-430 students that answer the most questions correctly!

Language: "In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded."

(Approved by Senate on 21 January 2009 – also see the section in this document on Assignments and evaluation.) « Conformément à la Charte des droits de l'étudiant de l'Université McGill, chaque étudiant a le droit de soumettre en français ou en anglais tout travail écrit devant être noté (sauf dans le cas des cours dont l'un des objets est la maîtrise d'une langue). »

Academic Integrity: "McGill University values academic integrity. Therefore, all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures. (Approved by Senate on 29 Jan. 2003) (see www.mcgill.ca/students/srr/honest/ for more information). If a student is suspected to have plagiarized or cheated on the quizzes, the situation will be handled through the Code of Student Conduct and Disciplinary Procedures by submitting evidence to the Faculty of Engineering Disciplinary Officer. "Additional policies governing academic issues which affect students can be found in the McGill Charter of Students' Rights" (The Handbook on Student Rights and Responsibilities is available here).

Plagiarism Software: Work submitted for evaluation as part of this course may be checked with text matching software within myCourses.

Copyright of course materials: © Instructor-generated course materials (e.g., handouts, notes, summaries, exam questions) are protected by law and may not be copied or distributed in any form or in any medium without explicit permission of the instructor. Note that infringements of copyright can be subject to follow up by the University under the Code of Student Conduct and Disciplinary Procedures.

Lecture recording available on zoom: Live lectures will be given during the scheduled time. The lectures will be recorded and made available through zoom. It is the responsibility of the student to ensure that the videos and associated material are not reproduced or placed in the public domain. This means that each student can use it for their educational (and research) purposes, but students cannot allow others to use it by putting it up on the Internet or by giving it or selling it to others who may also copy it and make it available. *Please refer to* McGill's Guidelines for Instructors and Students on Remote Teaching and Learning for further information.

COVID-19 Provincial Regulations: The provincial government has put in place a progressive regional alert and intervention system. As of December 9, 2021, Montreal City is at Level 4 – Maximum Alert (red). At that level, there will not be any in-person teaching activities. At Level 3 – Alert (orange), there may be some attempt of in-person teaching activities that will be discussed in class to ensure fairness and the security of all students.
https://www.quebec.ca/en/health/health-issues/a-z/2019-coronavirus/progressive-regional-alert-and-intervention-system/

Health and wellness resources at McGill: Student well-being is a priority for the University. Below are some suggested resources that all students have access to for free (paid through your tuitions). We highly encourage students to investigate and make use of the services available.

- Student Wellness Hub - All of McGill's health and wellness resources integrated into a single hub; includes urgent care, self-help, various events and workshops, and more. Visit the Virtual Hub at https://www.mcgill.ca/wellness-hub/
- Office for Students with Disabilities (OSD) - Works with students who have documented disabilities, mental health issues, chronic health conditions, or other impairments. Includes services such as note taking, exam accommodations, access technology, and student funding. Visit https://www.mcgill.ca/osd/student-resources
- McGill Engineering Student Centre (MESC) - Provides academic and career advising, wellness support, and peer tutoring services. Visit https://www.mcgill.ca/engineering/students/undergraduate/mesc
- Engineering Local Wellness Advisor (LWA, Miss Lauren Weber) - Trained clinicians here to orient and connect you with the appropriate resource(s) for your unique situation. To make an appointment, visit https://www.mcgill.ca/wellness-hub/get-support/local-wellness-advisors
- Suggested read for adapting to online learning and working from home: https://reporter.mcgill.ca/the-shift-to-working-and-learning-from-home/
- How to manage Zoom fatigue: https://www.mcgill.ca/tls/files/tls/tls_students_zoom_fatigue_final.pdf

Course Schedule (*tentative*)*

Week	Date	Sections – Learning Outcomes (instructor)	Topic	Comments/Assessments
1	7 Jan.	Introduction	Lecture 1	
	8 Jan.		*Tutorial 1 – Prerequisite review*	
2	12 Jan.	Waveguides – LO1 (OL)	Lecture 2	A1 given
	14 Jan.		Lecture 3	
	15 Jan.		*Tutorial 2 – Prerequisite review*	
3	19 Jan.		Lecture 4	
	21 Jan.		Lecture 5	
	22 Jan.		*Library Seminar 1/Tutorial 3*	Online Quiz #1 (ECSE 430)
4	26 Jan.	Semiconductor sources – LO2 (KM)	Lecture 6	A1 due, A2 given
	28 Jan.		Lecture 7	
	29 Jan.		Tutorial 4	
5	2 Feb.		Lecture 8	Paper topic due,
	4 Feb.		Lecture 9	
	5 Feb.		*Technical Seminar 2(lasers)/Tutorial 5*	Online Quiz #2 (ECSE 430)
6	9 Feb.	Optical Modulators – LO3 (OL)	Lecture 10	A2 due
	11 Feb.		Lecture 11	
	12 Feb.		*Tutorial 6*	
7	16 Feb.		Lecture 12	
	18 Feb.	Photodetector – LO4 (KM)	Lecture 13	Paper abstract due
	19 Feb.		*Tutorial 7*	
8	23 Feb.		Lecture 14	
	25 Feb.		Lecture 15	Midterm Examination #1
	26 Feb.		*Technical Seminar 3(TXRX)/Tutorial 8*	Online Quiz #3 (ECSE 430)
Spring Break (March 1-5) – no lectures, no homework. Have a restful break.				
9	9 Mar.	Optical Amplifiers – LO5 (KM)	Lecture 16	A3 given
	11 Mar.		Lecture 17	
	12 Mar.		*Technical Seminar 4 (nobel)/Tutorial 9*	Online Quiz #4 (ECSE 430)
10	16 Mar.	Systems and Applications – LO7 (OL)	Lecture 18	
	18 Mar.		Lecture 19	
	19 Mar.		*Techn. Seminar 5 (Optius)/Tutorial 10*	Online Quiz #5 (ECSE 430)
11	23 Mar.		Lecture 20	A3 due
	25 Mar.		Lecture 21	
	26 Mar.		*Techn. Seminar 6 (T&M)/Tutorial 11*	Online Quiz #6 (ECSE 430)
12	30 Mar.	T&M – LO6 (KM) (maybe swap with LO7 schedule)	Lecture 22	
	1 Apr.		Lecture 23	Midterm Examination #2
	2 Apr.		***Good Friday** – no tutorial*	
13	6 Apr.	Research Topics Presentations	Presentations	Final paper due, A4 given
	8 Apr.		Presentations	
	9 Apr.		*Tutorial 13*	
14	13 Apr.		Presentations	
	15 Apr.		Presentations	
	16 Apr.		*Tutorial 14*	A4 due

* In the event of extraordinary circumstances beyond the University's control, the content and/or evaluation in this course is subject to change.

Course Content

1. Dielectric waveguides (2 wk, 6 hrs)
    i. Planar dielectric waveguides
    ii. Optical fibers
    iii. Attenuation and dispersion

2. Semiconductor sources (2 wk, 6 hr)
    i. Basics of semiconductors
    ii. Structure and physical description of semiconductor lasers
    iii. Rate equation models for semiconductor lasers

3. Optical modulation (1.5 wk, 4.5 hr)
    i. Dynamic equations for direct modulation of semiconductor lasers
    ii. Physical description and models for electro-optical and electro-absorption modulators

4. Photodetection (1.5 wk, 4.5 hr)
    i. Principles of photodetection
    ii. *pn*, *pin*, and APD photodetectors

5. Optical amplifiers (1 wk, 3 hr)
    i. Basic amplifier properties
    ii. Erbium-doped fiber amplifiers, semiconductor optical amplifiers, Raman and Brillouin amplification

6. Systems and Applications (2 wk, 6 hr)
    i. Optical Communication Systems
    ii. Optical Switches and Processors
    iii. Passive components for systems: Directional couplers, Y-branch, Mach-Zehnder interferometer,Resonators

7. Measurements and instrumentation (1 wk, 3 hr)
    i. Time-domain versus frequency-domain characterization of optical signals
    ii. Optical spectrum analyzers, RF spectrum analyzers, sampling oscilloscopes.

Canadian Engineering Accreditation Board (CEAB) Curriculum Content

This course contributes the following curriculum category content:

CEAB curriculum category content	Number of AU's (Accreditation Units)	Description
Math	0	Mathematics include appropriate elements of linear algebra, differential and integral calculus, differential equations, probability, statistics, numerical analysis, and discrete mathematics
Natural science	0	Natural science includes elements of physics and chemistry, as well as life sciences and earth sciences. The subjects are intended to impart an understanding of natural phenomena and relationships through the use of analytical and/or experimental techniques.
Complementary studies	0	Complementary studies include the following areas of study to complement the technical content of the curriculum: engineering economics; the impact of technology on society; subject matter deals with central issues, methodologies, and thought processes of the arts, humanities and social sciences; management; oral and written communications; healthy and safety; professional ethics, equity and law; and sustainable development and environmental stewardship.
Engineering science	26	Engineering science involves the application of mathematics and natural science to practical problems. They may involve the development of mathematical or numerical techniques, modelling, simulation, and experimental procedures. Such subjects include, among others, applied aspects of strength of materials, fluid mechanics, thermodynamics, electrical and electronic circuits, soil mechanics, automatic control, aerodynamics, transport phenomena, elements of material science, geoscience, computer science, and environmental science.
Engineering design	26	Engineering design integrates mathematics, natural sciences, engineering sciences, and complementary studies in order to develop elements, systems, and processes to meet specific needs. It is a creative, iterative, and open-ended process, subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may also relate to economic, health, safety, environmental, societal or other interdisciplinary factors.

Accreditation units (AU) are defined on an hourly basis for an activity which is granted academic credit and for which the associated number of hours corresponds to the actual contact time: one hour of lecture (corresponding to 50 minutes of activity) = 1 AU; one hour of laboratory or scheduled tutorial = 0.5 AU. Classes of other than the nominal 50-minute duration are treated proportionally. In assessing the time assigned to determine the AU of various components of the curriculum, the actual instruction time exclusive of final examinations is used.

Graduating Student Attributes

This course contributes to the obtention of the following attributes:

Graduating attribute	KB	PA	IN	DE	ET	IT	CS	PR	IE	EE	EP	LL
Level descriptor			**D**	**D**								

I = Introduced; D = Developed; A = Applied

KB *- Knowledge Base for Engineering: Demonstrated competence in university-level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.*

PA *- Problem Analysis: An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.*

IN *– Investigation: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.*

DE *– Design: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, economic, environmental, cultural and societal considerations.*

ET *- Use of Engineering Tools: An ability to create, select, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.*

IT *- Individual and Team Work: An ability to work effectively as a member and leader in teams, preferably in a multidisciplinary setting.*

CS *- Communication Skills: An ability to communicate complex engineering concepts within the profession and with society at large. Such abilities include reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.*

PR *- Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.*

IE *- Impact of Engineering on Society and the Environment: An ability to analyze social and environmental aspects of engineering activities. Such abilities include an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society; the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.*

EE *- Ethics and Equity: An ability to apply professional ethics, accountability, and equity.*

EP *- Economics and Project Management: An ability to appropriately incorporate economics and business practices including project, risk and change management into the practice of engineering, and to understand their limitations.*

LL *- Life-Long Learning: An ability to identify and to address their own educational needs in a changing world, sufficiently to maintain their competence and contribute to the advancement of knowledge.*