Compact spectrometer on silicon nitride chip

Compared to silicon-on-insulator (SOI) platform, silicon nitride (Si$_3$N$_4$) is already emerging with complementary advantages for photonic integration due to low transmission loss, wide transparency range and more manufacturing flexibility [1]. Especially the transparent window of Si$_3$N$_4$ covers from 0.75 μm to 0.93 μm, which is an important therapeutic window for biological media due to negligible water absorption and minimal photo-damage to cells. At the same time the index contrast in Si$_3$N$_4$ waveguides (cladded by silica) is moderately high (~2 VS 1.45), which makes it relaxed to fabrication tolerance while keeps a compact footprint. Si$_3$N$_4$ can be deposited by Low Pressure Chemical Vapour Deposition (LPCVD) at high temperature (>700 °C) or by Plasma Enhanced Chemical Vapour Deposition (PECVD) at low temperature (<400 °C), which makes the manufacturing flexible to integrate with other components, such as laser sources and silicon-based photodetectors.

In view of the background above, we propose a compact spectrometer based on Si$_3$N$_4$ platform for on-chip spectroscopic analysis, which can be realized by high-resolution and multichannel arrayed waveguide grating (AWG) or echelle diffraction grating (EDG) with Si based detector array for photoelectric conversion, as shown in Fig.1.

![Fig. 1. Spectroscopic analysis system based on silicon nitride platform](image)

For the master students’ 4-6 months research internships, we focus on investigating a compact, high-resolution spectrometer in the very near-infrared wavelengths band. Design and measurement will be implemented in Zhejiang University during the internships. The fabrication can be accomplished in Université Paris-Sud if possible. There are two solutions, arrayed waveguide grating (AWG) and echelle diffraction grating (EDG) for the planar integrated spectrometer. In our lab, we have proposed the ultracompact (~40μm×50μm) 4×4 AWG by utilizing a novel design with overlapped free-propagation-regions (FPRs) [2] and the first reflective AWG integrated photonic-crystal micro-reflectors at the end of each arrayed waveguide [3]. An ultracompact triplexer with three channels located at 1310, 1490 and 1550 nm based on EDG also has been demonstrated [4]. Some device pictures are shown in Fig. 2-4. Most previous research works focus on the SOI platform for the wavelength division multiplexing application in optical communication system. The spectroscopic analyses on chip require much smaller channel spacing (higher resolution) and more number of channels for the spectrometer. However, as the resolution and the number of channels increase, the spectrometer footprint will become big. What’s worse, the phases on the waveguides need very precisely control for AWG while the big FPR introduce more thickness variation of the guiding layer, which leads to poor imaging quality for EDG outputs. To realize compact and high-resolution spectrometer on plane integrated chip is a challenge. We will investigate it on Si$_3$N$_4$ platform assisted with Vernier effect [5], active phase correction [6] or densely packed waveguide array (DPWA) [7] at output ports.

![Fig. 2. Ultra-compact AWG][2] ![Fig. 3. Reflective AWG][3] ![Fig. 4. echelle grating triplexer][4]


**Erik Forsberg** | Associate Professor
Center for Optical and Electromagnetic Research
Zijingang campus, East building 5, Room 211
Zhejiang University
Hangzhou 310058, P.R. China
Email: erikf@zju.edu.cn, erik.forsberg@jorcep.org
Phone: +86 186 5889 3006
Skype: erik.l.forsberg

Professor Sailing He, Fellow of IEEE, OSA, SPIE, and the EM Academy
Director, Centre for Optical and Electromagnetic Research,
Zhejiang University, China
http://mypage.zju.edu.cn/sailinghe