



HAL
open science

CRIGFs: Spectral filters, but also modal filters and combiners

Antoine Rouxel, Antoine Monmayrant, Pascal Dubreuil, Stéphane Calvez,
Olivier Gauthier-Lafaye

► **To cite this version:**

Antoine Rouxel, Antoine Monmayrant, Pascal Dubreuil, Stéphane Calvez, Olivier Gauthier-Lafaye. CRIGFs: Spectral filters, but also modal filters and combiners. 24th International Conference on Transparent Optical Networks (ICTON 2024), Jul 2024, Bari, Italy. pp.1-2, 10.1109/ICTON62926.2024.10647488 . hal-04682032

HAL Id: hal-04682032

<https://hal.science/hal-04682032>

Submitted on 10 Sep 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

CRIGFs : Spectral filters, but also modal filters and combiners

A. Rouxel, A. Monmayrant, P. Dubreuil, S. Calvez and O. Gauthier-Lafaye

LAAS-CNRS, Université de Toulouse, CNRS, France

Tel: (33) 5 61 33 78 80, e-mail: Olivier.gauthier-lafaye@laas.fr

ABSTRACT

CRIGF filters have been shown to exhibit Fano resonances based on mesoscopic localized modes. We will show how we can harness this to design high Q factor CRIGFs, or use selective excitations of part of these modes to use the CRIGF as modal spatial filters or combiners.

Keywords: CRIGF; Fano resonances, spectral filters, modal filters

1. INTRODUCTION

First introduced in 2012 [1], Cavity-Resonator-Integrated Grating Filters (CRIGFs) are a particular variant of Guided Mode Resonance Filters (GMRFs) that can act as spectrally selective filters for tightly focused beams under normal incidence [2]. In their most common form, they rely on a single-mode waveguide capped with a grating coupler (GC) positioned in-between two Distributed Bragg Gratings (DBR), providing a localized mode that can be addressed by the focused beam. Previous work had demonstrated the existence of multiple order radiative patterns in 1D CRIGFs that result from the interaction between the grating coupler and the Fabry-Perot modes confined by the two DBRs [3]. We recently demonstrated that these high order modes can be addressed selectively using spatially shaped beams, opening the way to their use as modal discriminators for applications such as Few-mode-fibers demultiplexing for example [4]. We will also show that using high-order modes addressing in CRIGFs allows to realize all optical linear and logical operations.

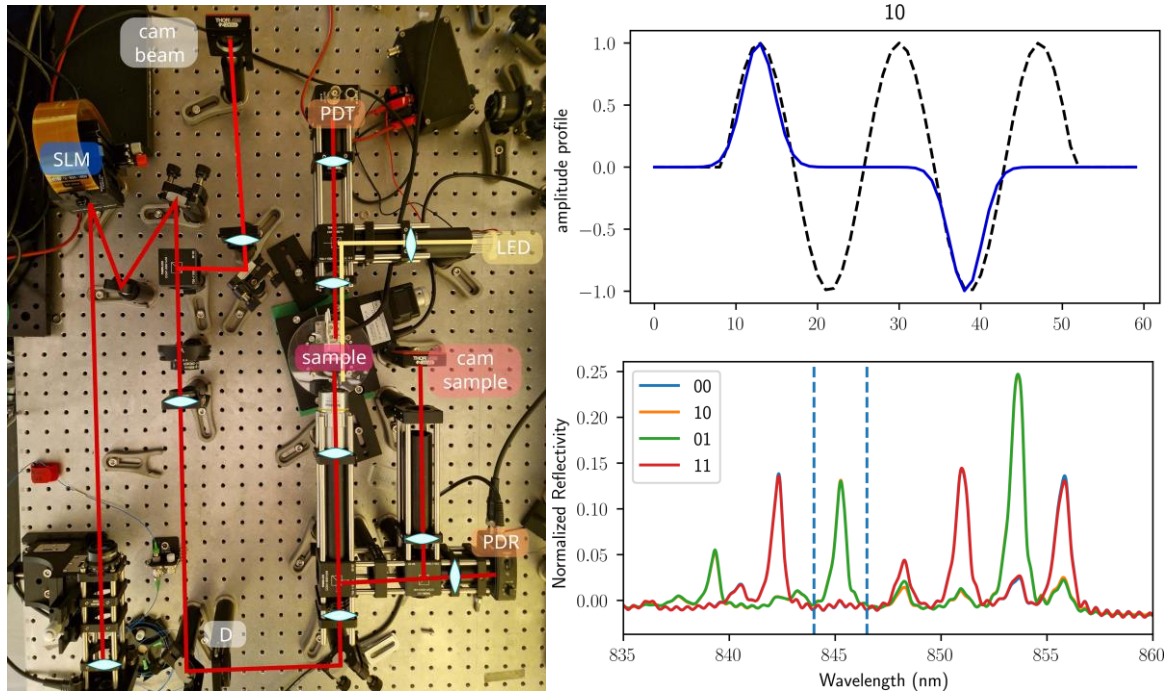


Figure 1. left : optical setup used. Top right: pentalobe mode shape (black dashed line) and mode superposition used in a typical combination experiment (blue line). Here the symbol 0 (nul phase) and 1 (π phase) is shown. Bottom right: reflectivity spectra recorded for different phases. The dashed blue lines highlight the pentalobe mode resonance peak.

2. RESULTS AND DISCUSSION

For selective mode excitation, we used a dedicated optical experiment depicted on figure 1. A fibered tunable laser (Broadsweeper850) is used as a source. The fiber output beam is collimated and propagates to a SLM used as a complex amplitude beam-shaper [5] (SLM on figure). The shaped diffracted beam is then focused on the sample through a x20 microscope objective. The reflected beam is analysed using either a camera (CAM

SAMPLE). The intensities of the transmitted and reflected beam are monitored with photodiodes (PDT and PDR on figure). A beamsplitter allows to monitor the shaped beam transformation for monitoring purposes (cam-beam on figure 1).

In the presentation, we will first present the CRIGF modes physical formation and origin. We will present theoretical and experimental results showing that these devices present localized modes whose coupling to the continuum can be finely tuned with simple geometrical parameters [6,7], thus resulting in Fano resonances with experimentally demonstrated Q factors as high as 10^3 , mostly limited by the internal losses of the demonstrators.

We will then show how these localized modes can be selectively addressed using our optical setup, allowing demultiplexing of complex 2D modes. Going further, investigations into how these devices could be used to perform optical linear binary computations have been carried out. This kind of optical mode combinations has been already demonstrated several years ago using Photonic Crystal cavities or plasmonic modes [8]. Here, our interest was to investigate whether the above-mentioned mesoscopic-size cavities and setup allow simple ways to implement logical operations.

For these experiments, we only considered using the highly excited modes shown on figure 1, top right. We shaped the input beam as shown in the figure, considering that 0 and 1 could be encoded on the sign of the input mode amplitude centered on the 1st and 4th lobe of the resonant mode. We show that (figure 1 bottom right) that the associated resonance reflexion peak is 0 for '00' and '11' peaks (i.e. when the 2 input beams will interfere destructively in the localized mode formation) and is maximum when the input phase beam components are '01' or '10' (i.e. when the input beam amplitudes shapes like the resonant mode). This can be considered as a XOR logical gate.

3. CONCLUSIONS

CRIGF filters can be seen as mesoscopic-size optical devices that allow to control the interaction of a localised mode with input and output modes in the continuum. We successfully used them to demonstrate logical operations between 2 modes components, and opens discussions on their potential use as optical demultiplexers or multiplexers for multimodal transmission or manipulation of information.

ACKNOWLEDGEMENTS

Authors acknowledge support from the LAAS clean-room, member of the French RENATECH network.

REFERENCES

1. K. Hatanaka, T. Majima, K. Kintaka, J. Inoue, K. Nishio, Y. Awatsuji, and S. Ura, "Cavity-resonator-integrated guided-mode resonance filter consisting of curved gratings," *Electron. Lett.* **48**, 717–718 (2012).
2. X. Buet, E. Daran, D. Belharet, F. Lozes-Dupuy, A. Monmayrant, and O. Gauthier-Lafaye, "High angular tolerance and reflectivity with narrow bandwidth cavity-resonator-integrated guided-mode resonance filter," *Opt. Express* **20**, 9322–9327 (2012).
3. R. Laberdesque, O. Gauthier-Lafaye, H. Camon, A. Monmayrant, M. Petit, O. Demichel, and B. Cluzel, "High-order modes in cavity-resonator-integrated guided-mode resonance filters (CRIGFs)," *J. Opt. Soc. Am. A* **32**, 1973 (2015).
4. A. Rouxel, O. Gauthier-Lafaye, A. Monmayrant, and S. Calvez, "Selective excitation of high-order modes in two-dimensional cavity resonator integrated grating filters," *Opt. Lett.* **49**, 1512 (2024).
5. J. A. Davis, D. M. Cottrell, J. Campos, M. J. Yzuel, and I. Moreno, "Encoding amplitude information onto phase-only filters," *Appl. Opt.* **38**, 5004 (1999).
6. A.-L. Fehrembach, E. Popov, E. Hemsley, A. Monmayrant, O. Gauthier-Lafaye, and S. Calvez, "Cavity-resonator integrated bi-atom grating coupler for enhanced second-harmonic generation," *Opt. Express* **30**, 38789 (2022).
7. E. Hemsley, O. Gauthier-Lafaye, A. Monmayrant, P. Dubreuil, S. Calvez, A.-L. Fehrembach, and E. Popov, "Critical coupling in cavity-resonant integrated-grating filters (CRIGFs)," *Opt. Express* **31**, 27274 (2023).
8. S. Jiao, J. Liu, L. Zhang, F. Yu, G. Zuo, J. Zhang, F. Zhao, W. Lin, L. Shao, Peng Cheng Laboratory, Shenzhen 518055, China, Department of Physics, The Hong Kong University of Science and Technology, Hong Kong 999077, China, and Department of Electrical and Electronic Engineering, Southern University of Science and Technology, Shenzhen 518055, China, "All-optical logic gate computing for high-speed parallel information processing," *Opto-Electron. Sci.* **1**, 220010–220010 (2022).