Supplementary Information: Transformation optics based ultra-compact high-Q micro-ring-resonator with high-precision locking

Shuai Cui[1,2], Yuan Yu[1,2,3]✉, Zhao Pan[1,2], Jiayao Su[1,2], Lifeng Cai[1,2], Dingshan Gao[1,2,3]✉, Fangzheng Zhang[4], Xinliang Zhang[1,2,3]

[1]Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology, Wuhan, 430074, China

[2]School of Optical and Electronic Information, Huazhong University of Science and Technology, Wuhan, 430074, China

[3]Optics Valley Laboratory, Wuhan, 430074, China

[4]National Key Laboratory of Microwave Photonics, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China

✉e-mail: yuan_yu@hust.edu.cn; dsgao@hust.edu.cn

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I. Simulation Parameters for Different Adiabatic Curves

To further explore the compactness and adiabatic properties of TO, we analyze and compare four curve types: TO designed curves, Euler bending curves, Bezier curves, and circular arcs with a constant bending radius. For consistency, the uniform waveguide widths for all four curves are set as 2 μm. The parameters for each curve are optimized to ensure high-order mode crosstalk remained below -20 dB. For Euler bending curve, we set R_{min} and R_{max} as respective 25 and 1200 μm, yielding an effective radius R_{eff} of 49 μm. For Bezier curve, the curvature is determined by two intermediate points defined as (R(1−B),0) and (R, B), where B (a unitless number) is referred to as the "Bezier number". This parameter is optimized to achieve the best resonator performance, resulting in a Bezier number of B=0.2 and an R_{eff} of 50 μm. Lastly, for circular arc with a constant bending radius, the bending radius is set as 128 μm to satisfy the low excitation of high-order modes.

II. Measuring the Transmission of MRR Based on VNA

A microwave photonic link illustrated in Fig. S1 is performed to measure the transmission of MRR using a VNA. A tunable laser source (TLS, NKT Basik E15) launches a continuous wave (CW) light into a phase-modulator (PM, Covega Mach-40), which is controlled by a polarization controller (PC_1). The modulated signal passes through an optical bandpass filter (OBPF) to remove one of the first-order sidebands, generating a single-sideband (SSB) signal. This SSB signal is amplified by an erbium-doped fiber amplifier (EDFA), and its polarization state is adjusted to be aligned with the principle polarization axis of the device under test (DUT) by PC_2. Then, the SSB signal is coupled into the DUT, which contains the fabricated MRR, via tapered optical fibers (OMT-APC-TJ-1M). The optical sideband sweeps across the resonant notch of the MRR, whose transmission spectrum is recorded by the magnitude of the sideband. Then the optical signal output from MRR is detected by a high-speed photodetector

(PD, SHF AGBerlin) and the beating signal between optical carrier and sideband is generated. Therefore, a microwave photonic notch filter (MPNF) recording the transmission spectrum of MRR is obtained. By using a VNA to measure the frequency response of MPNF, the transmission spectrum of MRR is obtained.

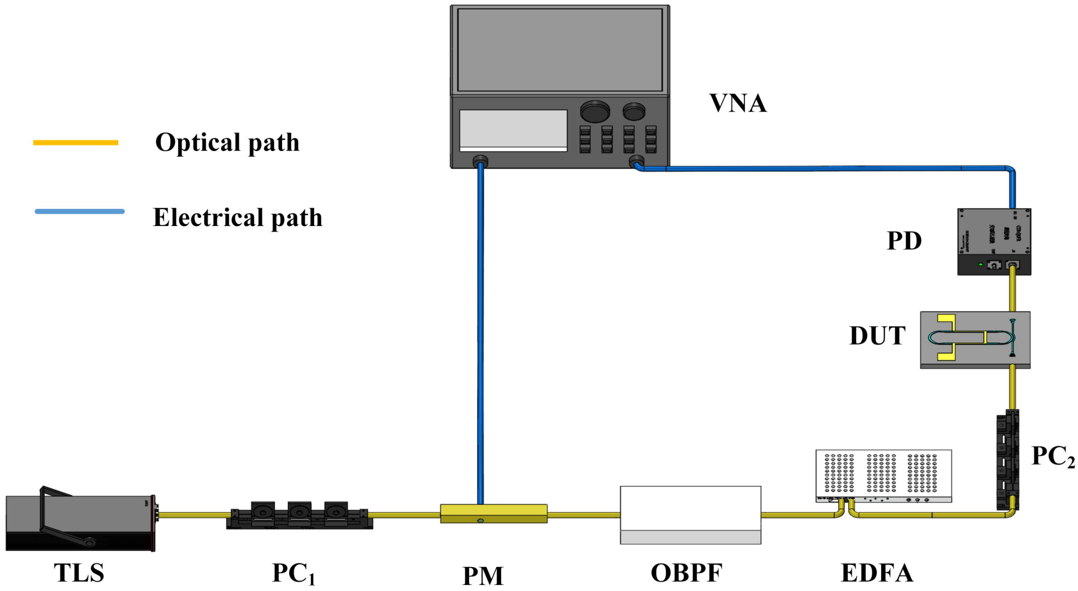

Fig. S1 Experimental setup for characterizing the Q factor of the fabricated ultrahigh-Q MRR using VNA. TLS: tunable laser source; PC: polarization controller; PM: phase modulator; OBPF: optical bandpass filter; EDFA: erbium-doped fiber amplifier; DUT: device under test; PD: photodetector; VNA: vector network analyzer.

III. Implementing an MPBF Based on MRR

Fig. S2 depicts the experimental configuration for characterizing the open-loop frequency response of the OEO using a VNA. The setup begins with a TLS emitting a CW light. A polarization controller (PC$_1$) is used to adjust the polarization state of CW light, which then undergoes phase modulation in a PM. The phase-modulated optical signal is transmitted over a 100-meter SMF. After PC$_2$, the phase-modulated signal is routed to the DUT, which contains the fabricated MRR. Then the phase-modulated signal is converted to intensity signal by MRR and detected by PD, generating a microwave photonic bandpass filter (MPBF). An EA is employed to boost the microwave power. Then the amplified microwave signal is routed to the VNA, performing precise measurement of the MPBF frequency response.

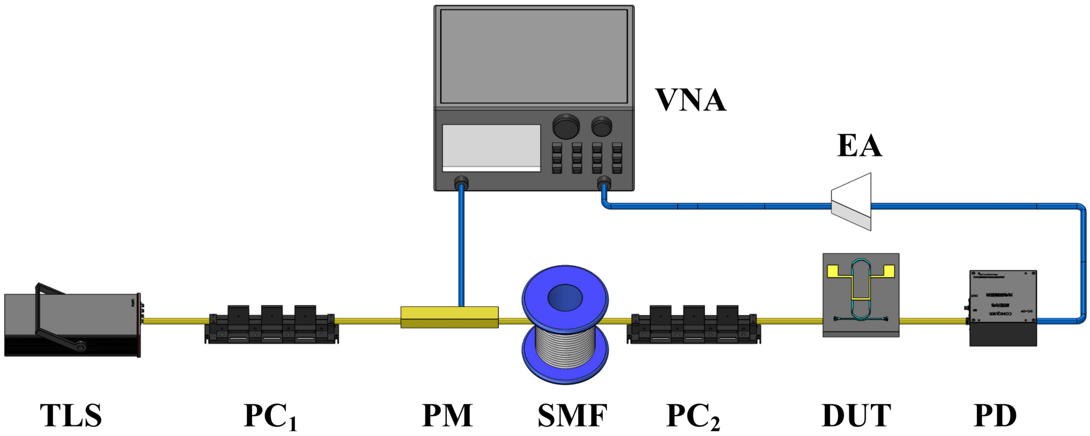

Fig. S2 Experimental setup of measuring the amplitude-frequency response of the MRR-based MPBF. TLS: tunable laser source; PC: polarization controller; PM: phase modulator; SMF: single-mode fiber; DUT: device under test; PD: photodetector; EA: electrical amplifier; VNA: vector network analyzer.