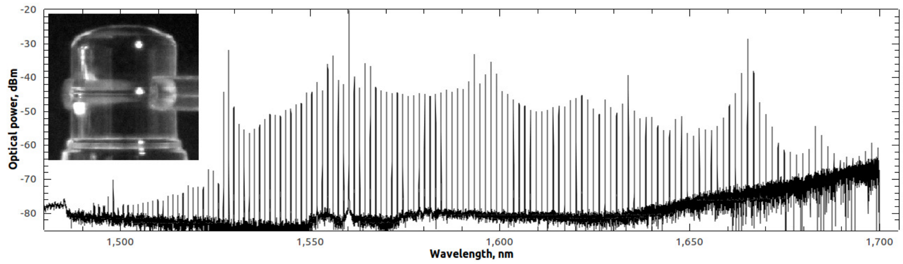

Fig. 7. Frequency comb observed in a resonator with an engineered spectrum. The $TE_{1101,1101,1}$ mode near 1560.3 nm (loaded $Q = 8.4 \times 10^7$, intrinsic $Q = 2 \times 10^8$) was pumped. Resonator diameter is 403 µm. Over a hundred comb lines spanning more than 200 nm (23.5 THz), limited by OSA range, are observed with only 50 mW of optical pump power.

This behavior could be evidence of hard comb excitation [24]. The envelope of the generated comb could become more or less regular compared to Fig. 7 depending on coupling conditions. MgF_2 is known to have 4 Raman active phonon modes [25], of which the 410 cm^{-1} mode is the strongest. With a pump at 1560.3 nm the Raman Stokes wavelength is expected to be 1667 nm. Raman gain might explain the asymmetry of the comb envelope visible in Fig. 7. However, the sharp drop below 1530 nm suggests that mode crossing could still be involved.

6. Discussion

Comparing our results to previously reported combs in MgF_2 (Table 1), one can see that the engineered cavity reported in this study demonstrates the best combination of pump power and comb span and also the largest comb repetition rate obtained with a MgF_2 resonator.

Table 1. Parameters of Various MgF_2 Microresonator-based Frequency Combs

Reference	FSR, GHz (diameter, µm)	Optical Q factor near λ = 1.55 µm	Pump, mW	Pump λ, µm	Comb span, nm
[9]	107 (700)	$>10^9$	600	2.45	~200
[8]	68 (1000)	$\sim 2 \times 10^8$	500	1.56	~300
[13]	34.67 (2000)	10^9	2	1.543	~20
This work	172.44 (403)	$\sim 2 \times 10^8$	50	1.56	>200

A low-power comb presented in ref [13]. spans 20 nm with pump power of 2 mW. We found, however, that a simple increase of the pump power doesn't always produce a broader comb. While we often observed 20 nm spanning combs with a few milliwatts of pump power in large resonators, further increase to 50 mW only produced a comb span of 40 nm as shown in Fig. 4. It should also be noted that during fabrication of the engineered resonator, its Q was initially lower, and we observed comb generation starting with N = 2. Non-optimal angle and core diameter of the fiber coupler explains the relatively low (50%) coupling efficiencies observed in the experiments.

7. Conclusion

We demonstrate that by changing the ratio of cavity linewidth to its dispersion one can control the number N of the cavity FSRs separating the first comb sidebands from the pump. We present a comb spanning over 200 nm with a pump power 10 times lower than previously reported. We expect that careful engineering of the cavity spectrum is a path to low threshold, high efficiency octave spanning microcavity comb generation that will enable compact optical clocks and other precision frequency metrology devices.

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