Optical Frequency Comb Generation for RF Photonics Applications

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Introduction

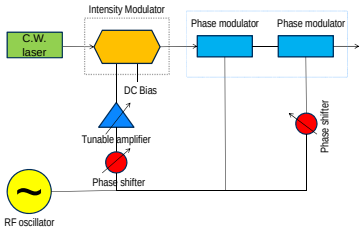
➢ Optical frequency combs are comprised by periodical spectral lines with repetition rates which is determined by Radio-Frequency (RF) oscillator.

➢ To the best of our knowledge, we have achieved the flattest as well as very broadb and stable combs (One comb has 38 lines within 1dB variation out of 61 lines in total as well as the other comb has 51 lines within 5.4dB variation out of 63 lines in total). These combs have therefore many potential interesting applications in the optical communications and RF photonics field.

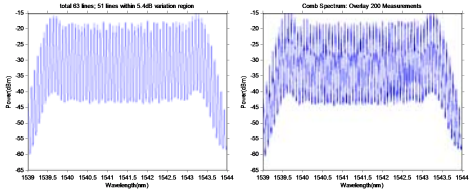
➢ We also demonstrate some interesting results with our combs on applications of generating high-fidelity short light pulses for high speed optical fiber communication system, and RF photonics filtering, and etc.

Frequency Comb Generator 1 — Traditional Scheme

➢ Initially we built a frequency comb based on the well-known scheme[1] as below

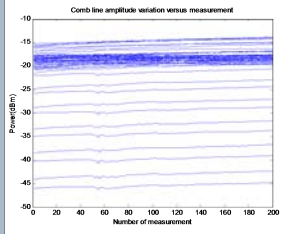


➢ The output frequency comb spectrum has 51 lines within 5.4dB variation out of 63 lines in total.



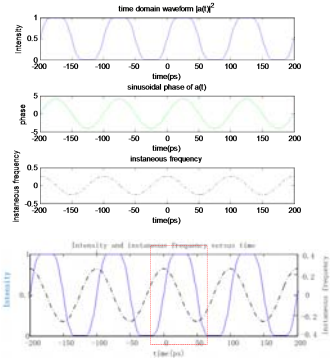
Initial Comb With Bumps

Long Term Measurement Overlay 200 Spectra for 7 hours.



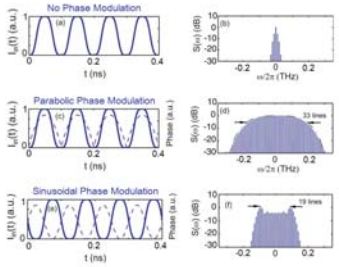
The Central 51 Comb Lines Are Within 0.5dB Variation. Good Stability!

➢ Mechanism for broadening and flattening the comb



Strategy 1 to Improve Comb: Realize <50% Duty Cycle
Solution: Use Two Intensity Modulators

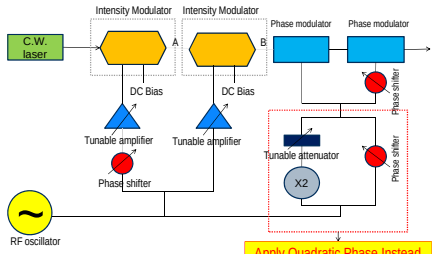
➢ Time to Frequency Mapping[2]



Strategy 2 to Improve Comb: Apply Parabolic Phase, Instead of Sinusoidal Phase
Solution: Carefully Tune the Power Difference Between the First and Second Harmonics (Taylor Expansion)

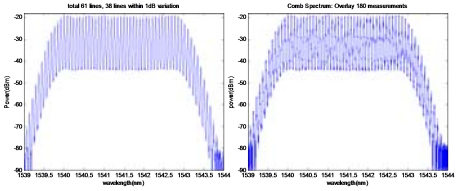
Frequency Comb Generator 2 — New Scheme

➢Frequency Comb Generator 2 Experimental Setup



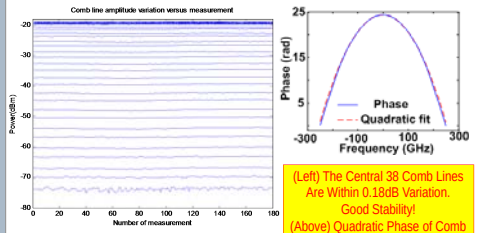
Apply Quadratic Phase Instead Of Sinusoidal Phase

➢ The output frequency comb has 36 lines within 0.6dB or 38 lines within 1dB variation out of 61 lines in total.



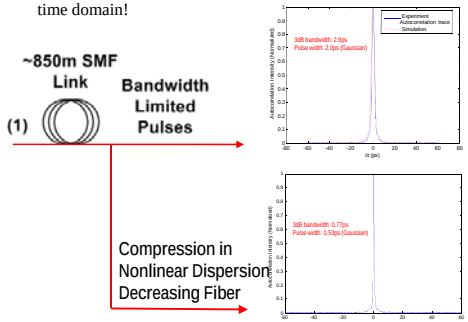
Initial Flat Comb

Long Term Measurement Overlay 180 Spectra for 7 Hours.



(Left) The Central 38 Comb Lines Are Within 0.18dB Variation. Good Stability!
(Above) Quadratic Phase of Comb

➢ If we connect the output comb with ~850m single mode fiber (SMF), the phase of comb would be compensated and we will see very short pulses with 100ps repetition rate in time domain!



➢ The generation of high-fidelity short light pulses is interesting for high speed optical fiber communications.

Comb Flatness & Broadness Comparison

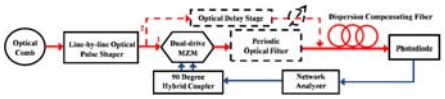
Comb Scheme	Broadness	Flatness	Group
Dual Drive MZM	27 lines	11 lines within 1.1dB	NICT[3]
Dual-sine-wave PM	38 lines	11 lines within 2dB	UCF[4]
IM-PM	63 lines	51 lines within 5.4dB	Purdue
PM-CFBG-PM	81 lines	61 lines within 7.4dB	NTT[5]
Modified IM-PM	61 lines	38 lines within 1dB	Purdue

NTT Applied More Power On Phase Modulator Than We Did!

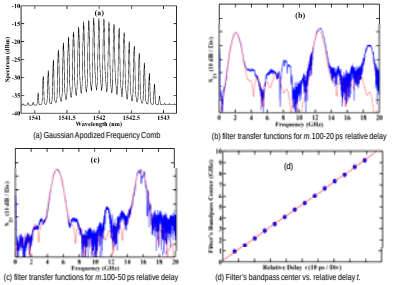
We Achieved the Flattest Comb!

Application of RF photonics filtering[6]

➢We implemented tunable programmable microwave photonic filters with frequency comb, which enables to scale these filters to large number of taps.



➢We used optical line-by-line pulse shaper to program tap weights and shape the filter's bandpass. For the first time we demonstrated a simple technique using a programmable optical delay line to uniformly tune the bandpass filter center across its free spectral range (FSR).



Conclusion

➢We achieved a very flat (36 lines within 0.6dB variation or 38 lines within 1dB variation), broad (61 lines in total), and stable frequency comb, which is suitable for interesting applications in the optical communications and RF photonics.

➢With this comb source, we demonstrated the generation of very short pulse (pulse width: 2ps or 0.5ps after compression in Nonlinear fiber), as well as tunable and programmable microwave photonic filter.

Acknowledgement

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