Octave Spanning Frequency Combs Directly from the Laser and Single-Cycle Pulse Synthesis

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Outline

I. Octave Spanning, Prism-Less Ti:Sapphire Laser

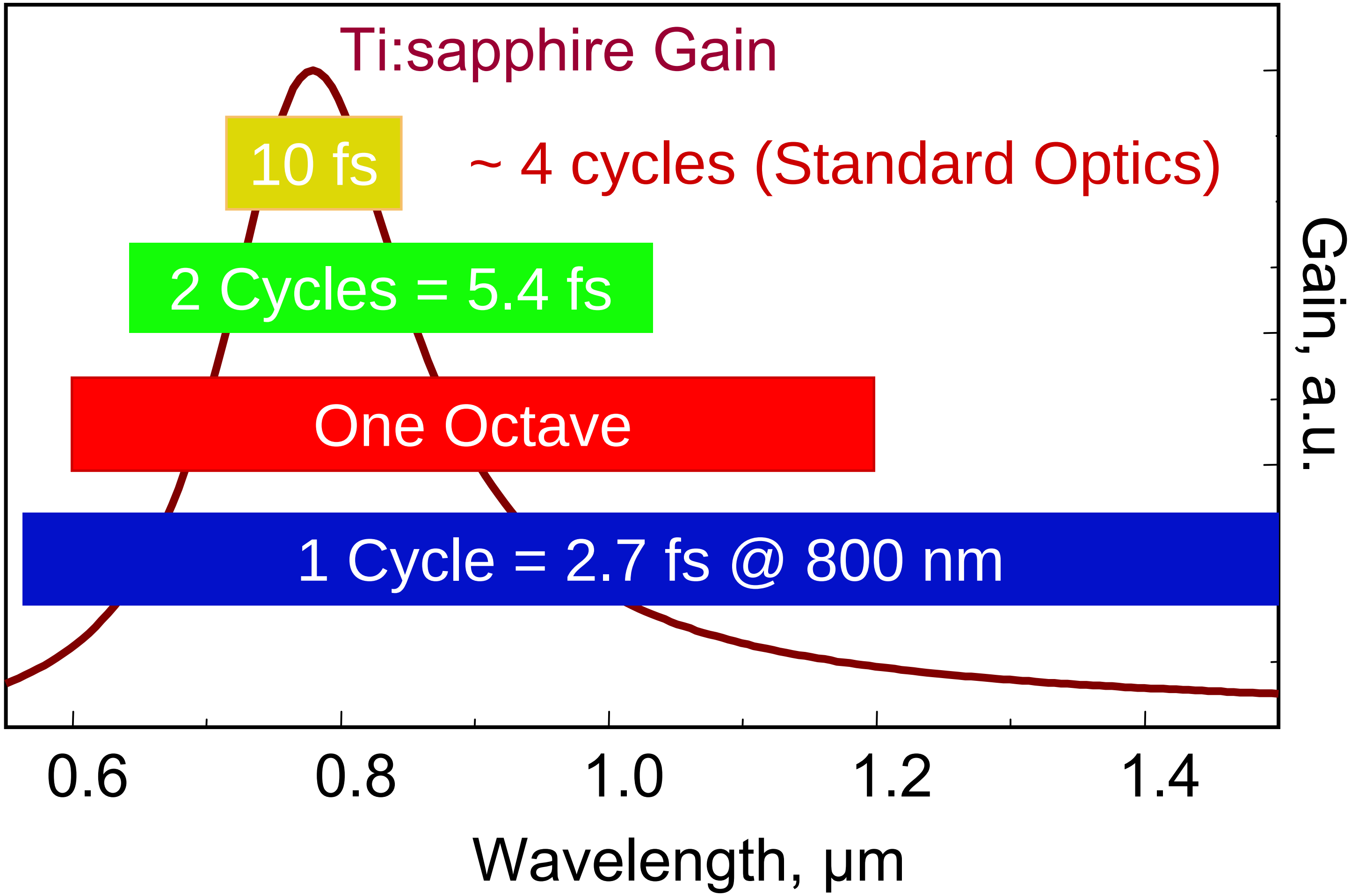
II. Broadband Dispersion Compensating Mirror Pairs

III. Ultra broadband Comb or Single-Cycle Pulse Synthesis

IV. Electronic Optical Phase Detection

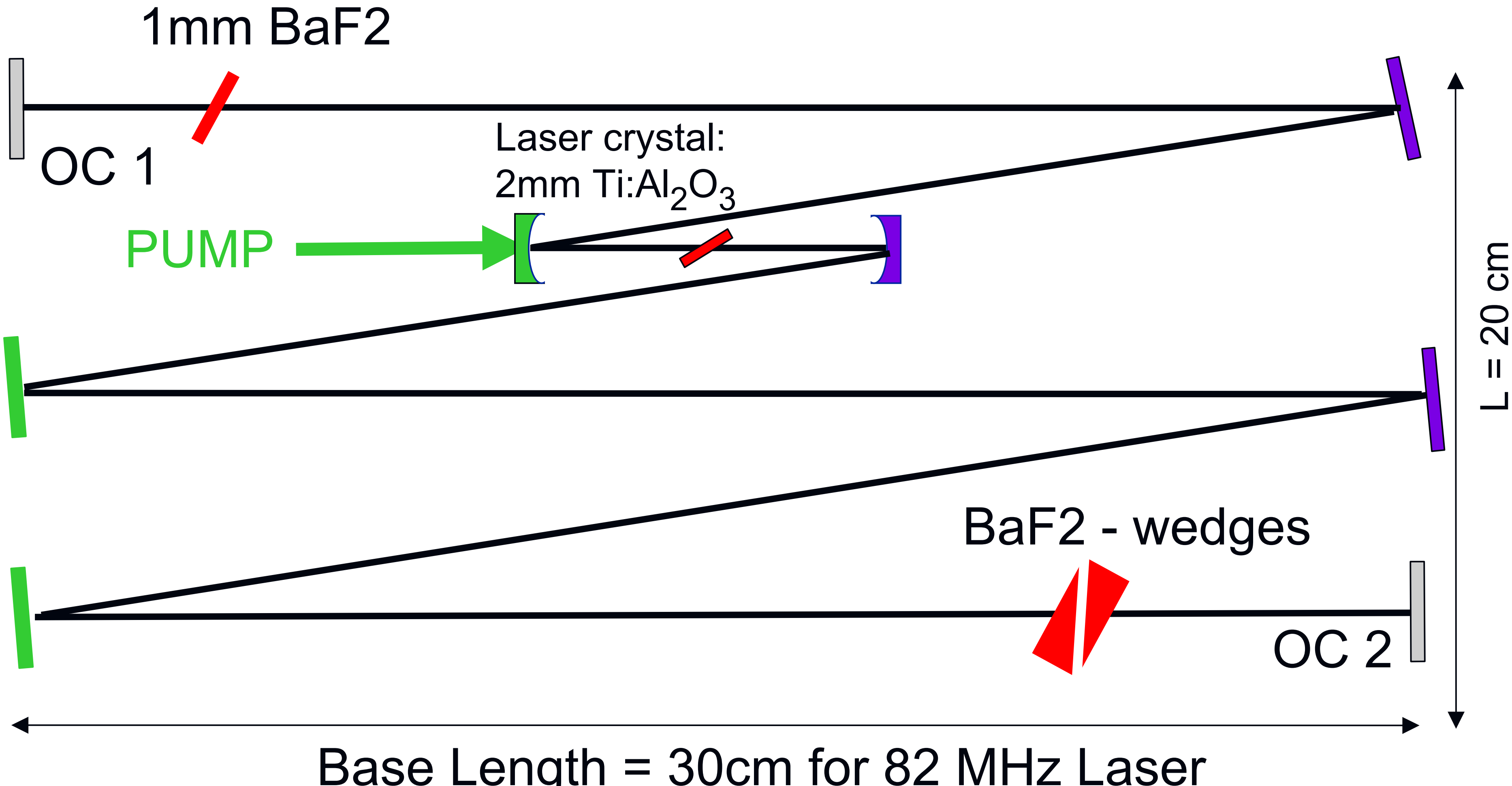
VI. Conclusion

Bandwidth Requirements

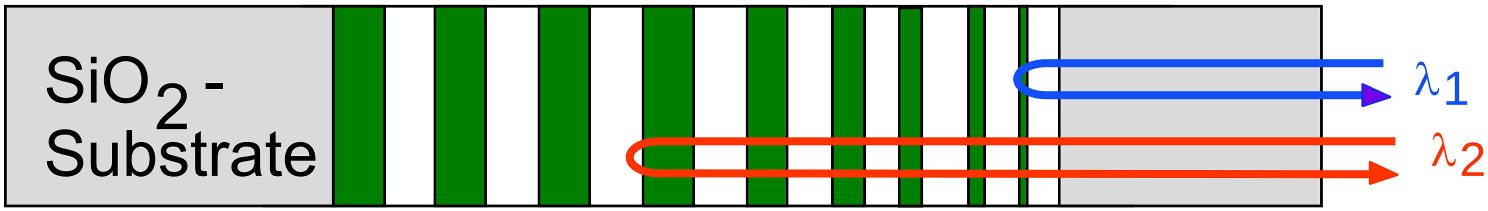


Mirrors: High Reflectivity + Correct Group Delay

Broadband, Prismless Ti:sapphire Laser

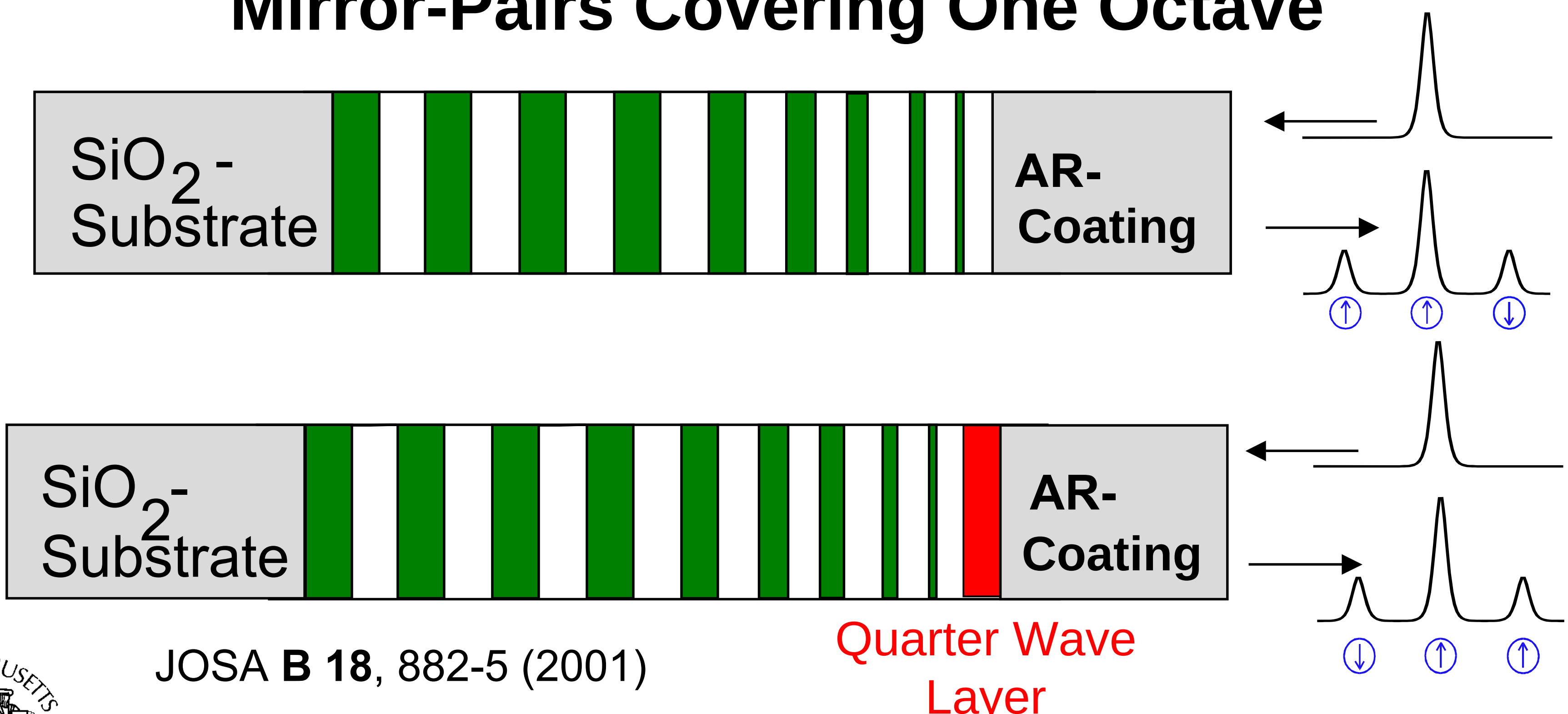


Double-Chirped Mirrors



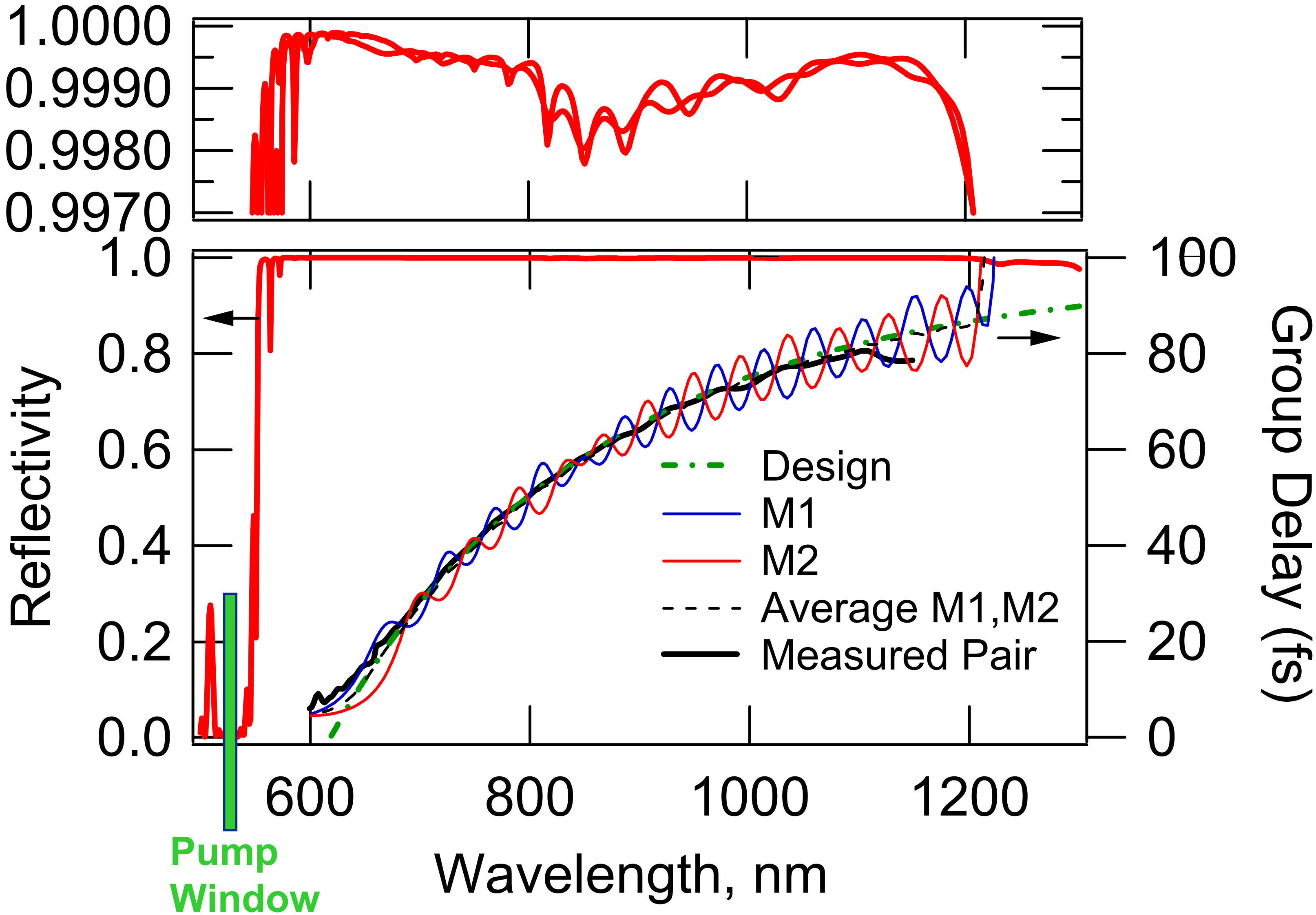
Opt. Lett. **33**, 831-3 (1997)

Mirror-Pairs Covering One Octave

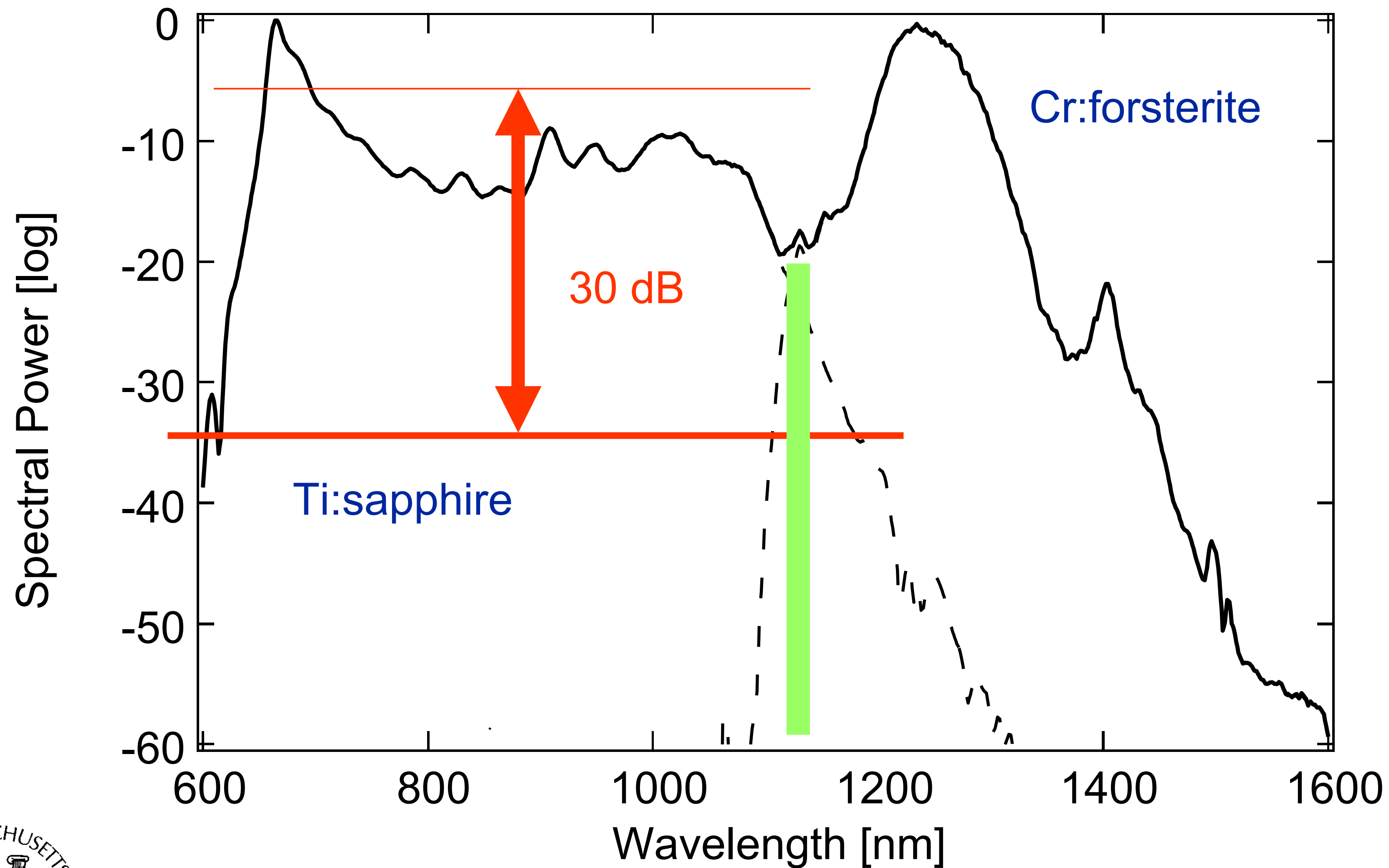


JOSA **B 18**, 882-5 (2001)

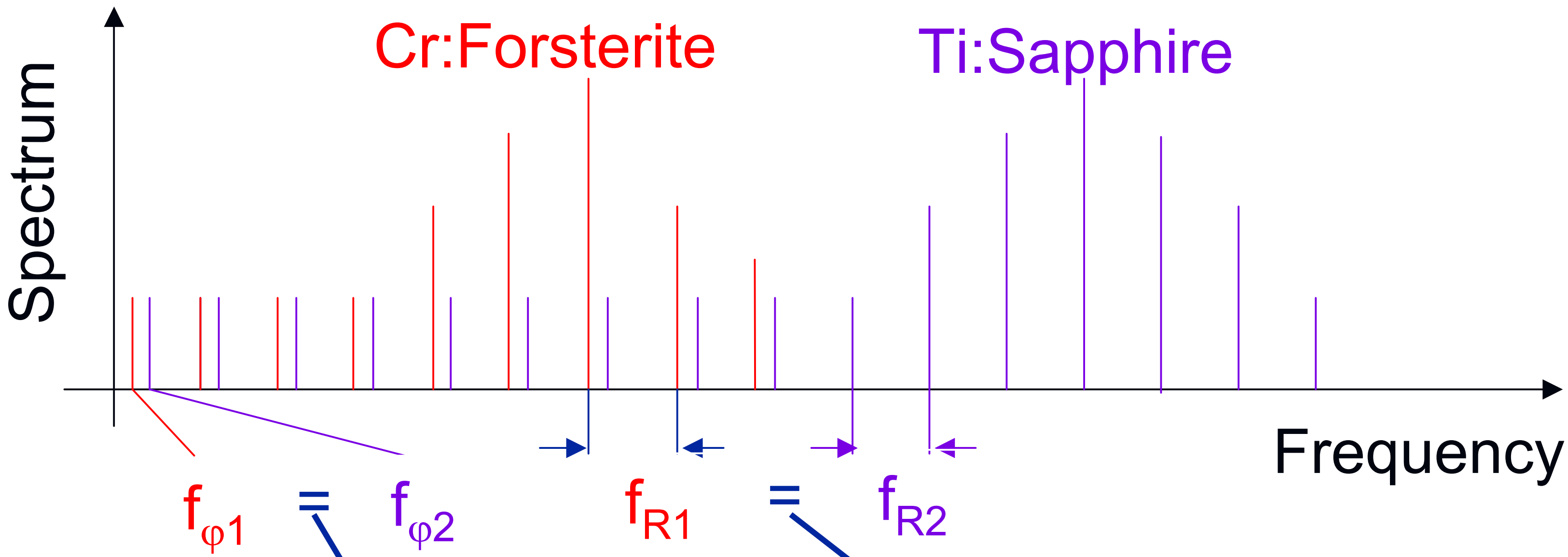
Double-Chirped Mirror Pairs



Laser Spectra



Coherent Superposition of Two ML-Lasers



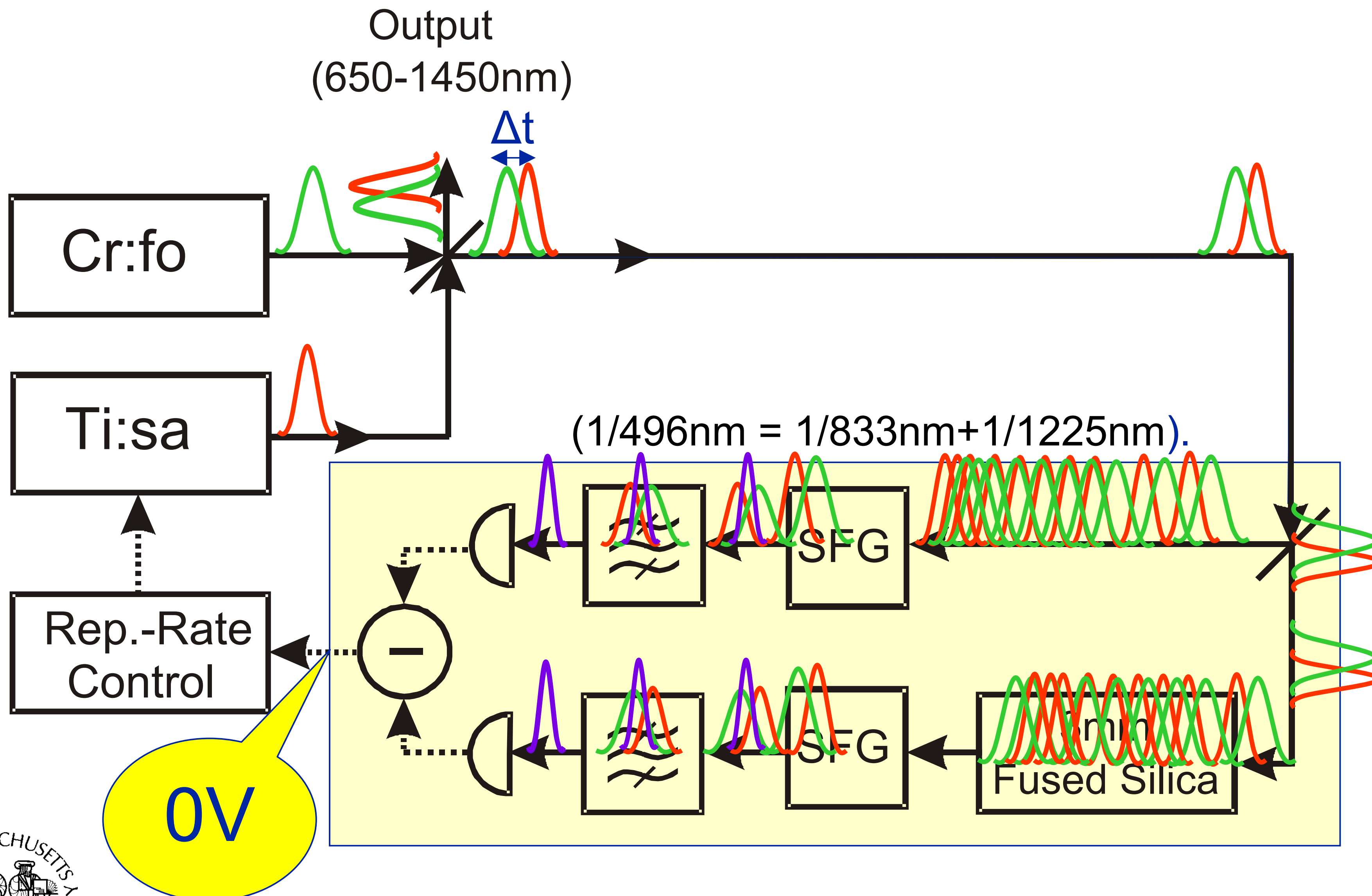
$f_{\varphi 1} = f_{\varphi 2}$: Position of the mode combs must match (→ heterodyne beat between the two lasers can be used.)

$f_{R1} = f_{R2}$: Repetition rates must match (→ build PLL to lock the rep.rates.)

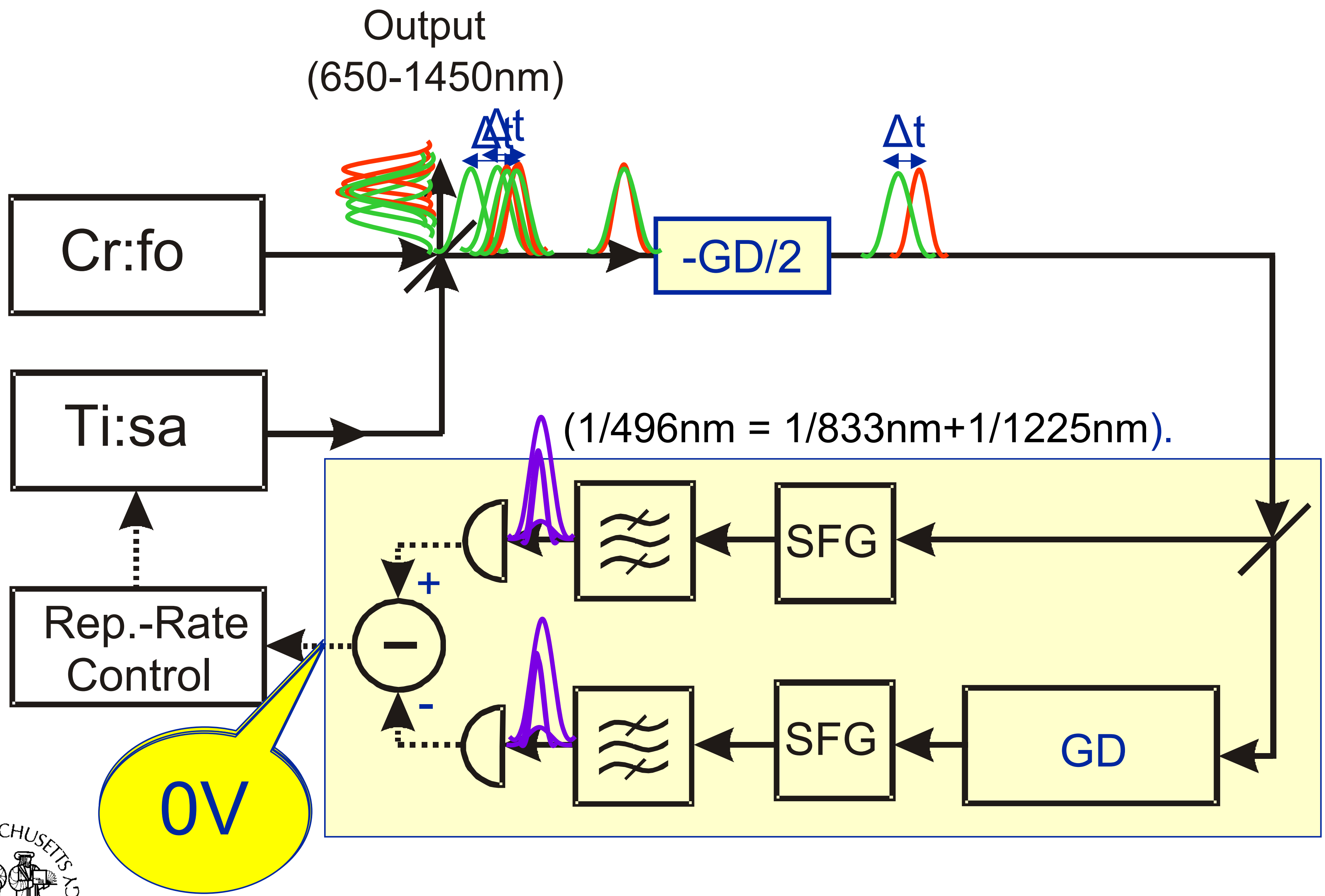
Passive: A. Leitensdorfer et al., Opt. Lett. 20, 916-918 (1995)
Z. Wei et al., Opt. Lett 26, 1806-1808 (2001)

Active: R. K. Shelton et al., Opt. Lett. 27, 312-314 (2002)

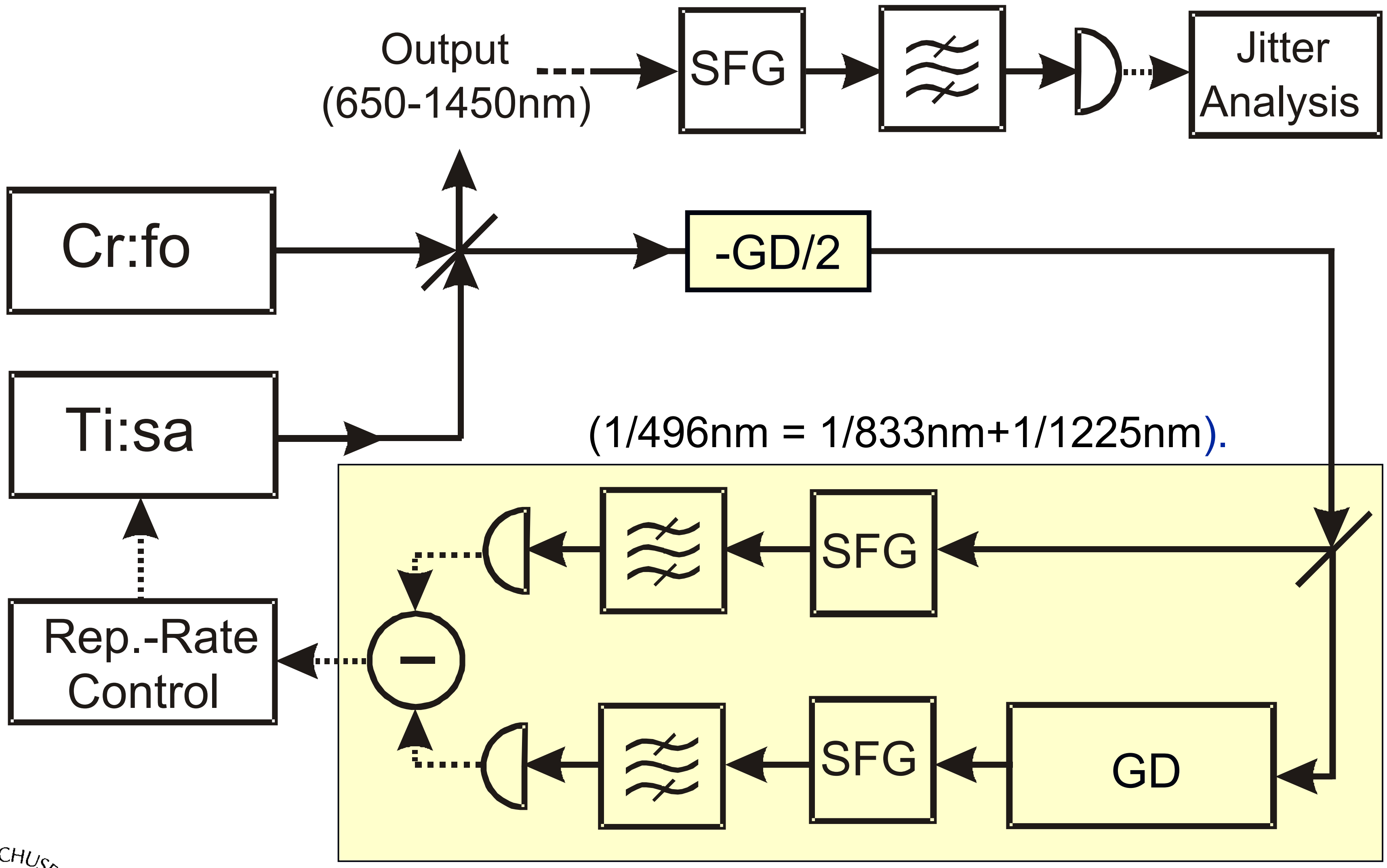
Balanced Cross-Correlator



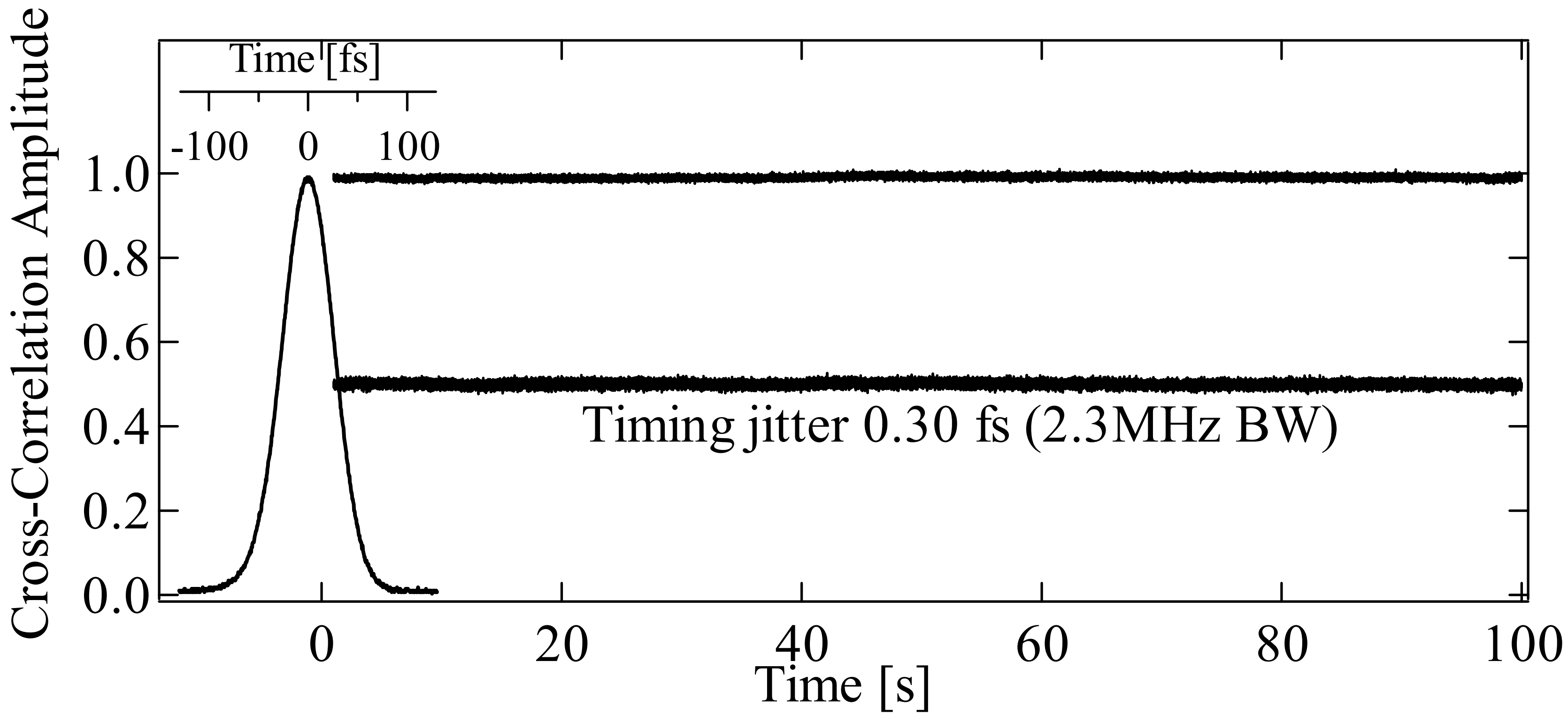
Balanced Cross-Correlator



Measuring the residual timing jitter



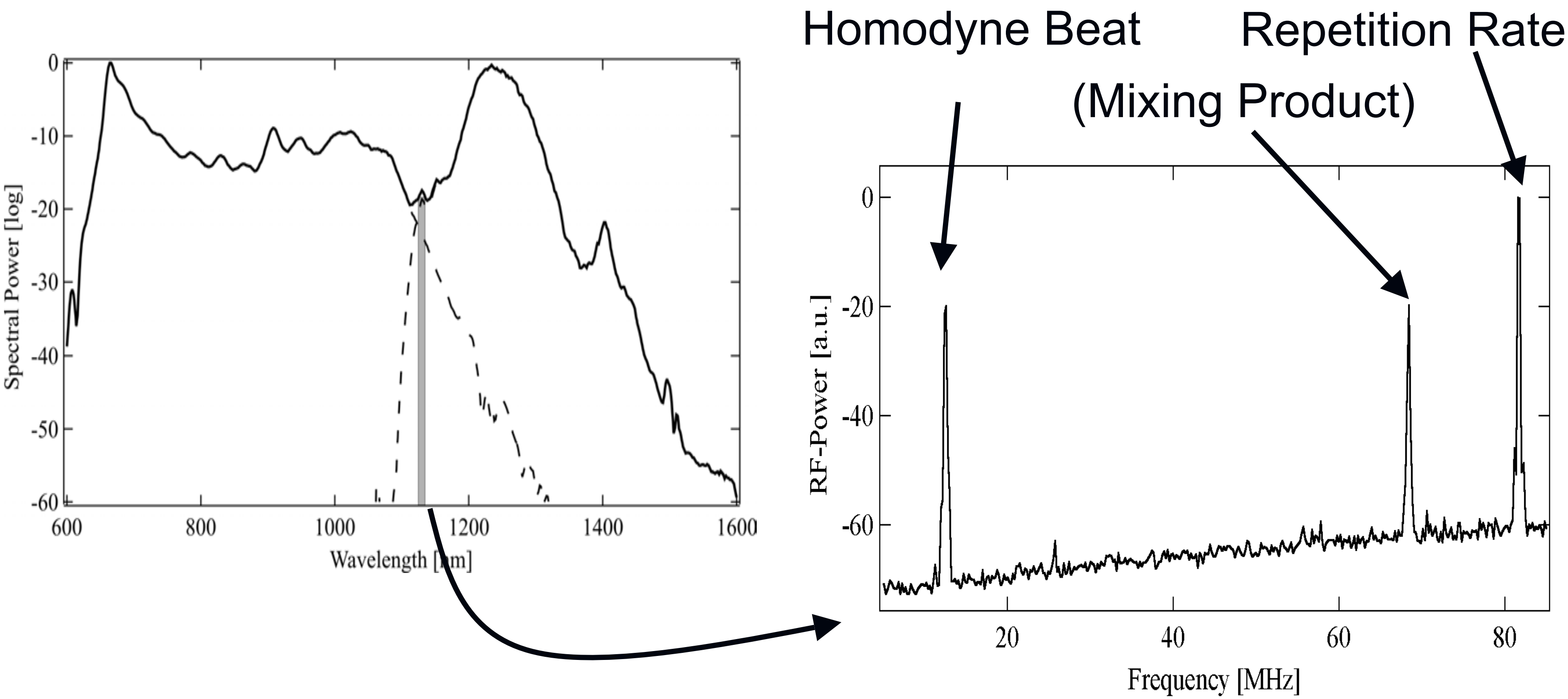
Experimental result: Residual timing-jitter



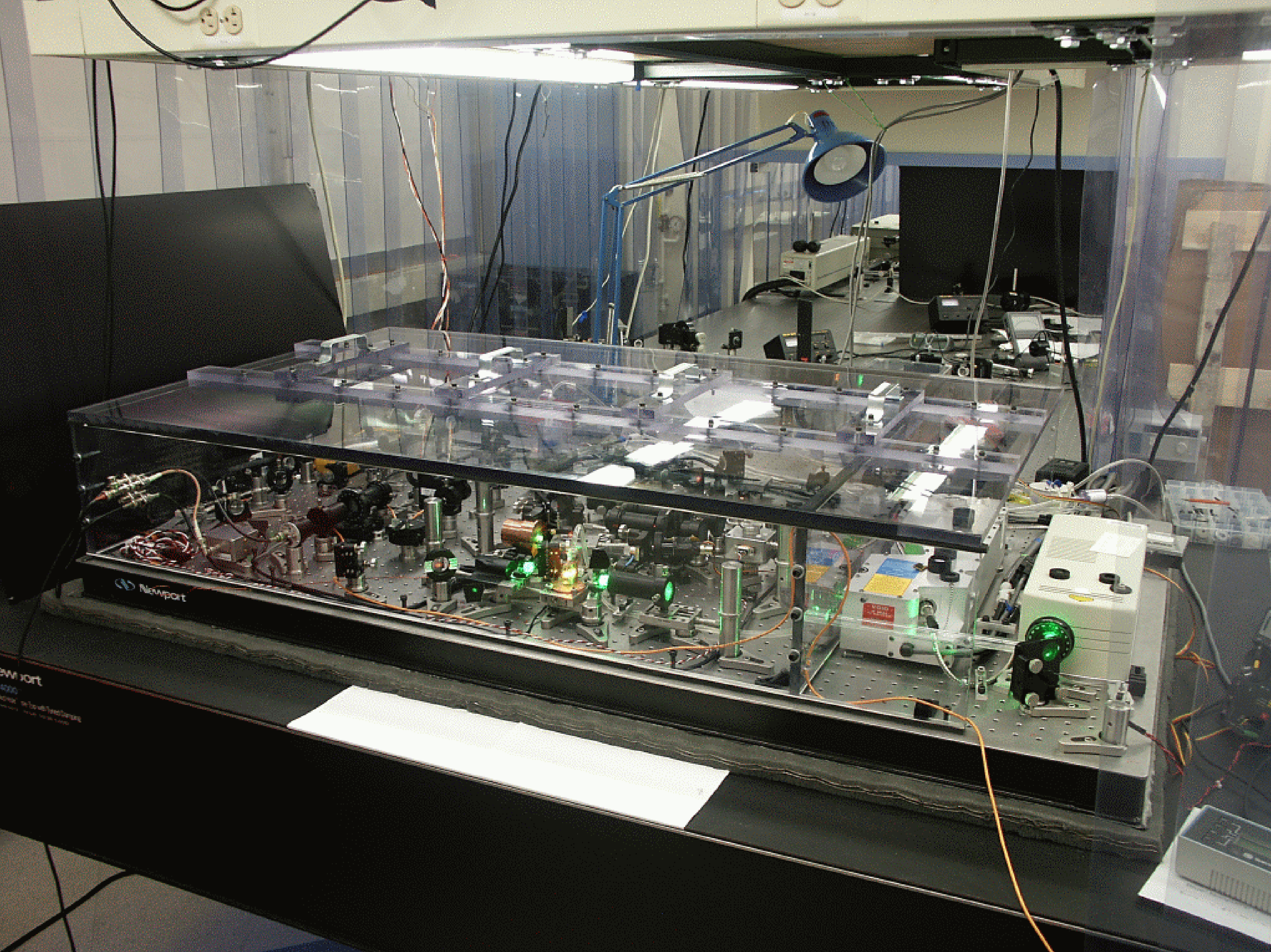
The residual out-of-loop timing-jitter measured from 10mHz to 2.3 MHz is 300 as (a tenth of an optical cycle)

L. Ma et al., Phys. Rev. A, **64** (2001)

Detection of Carrier-Envelope Phase Difference



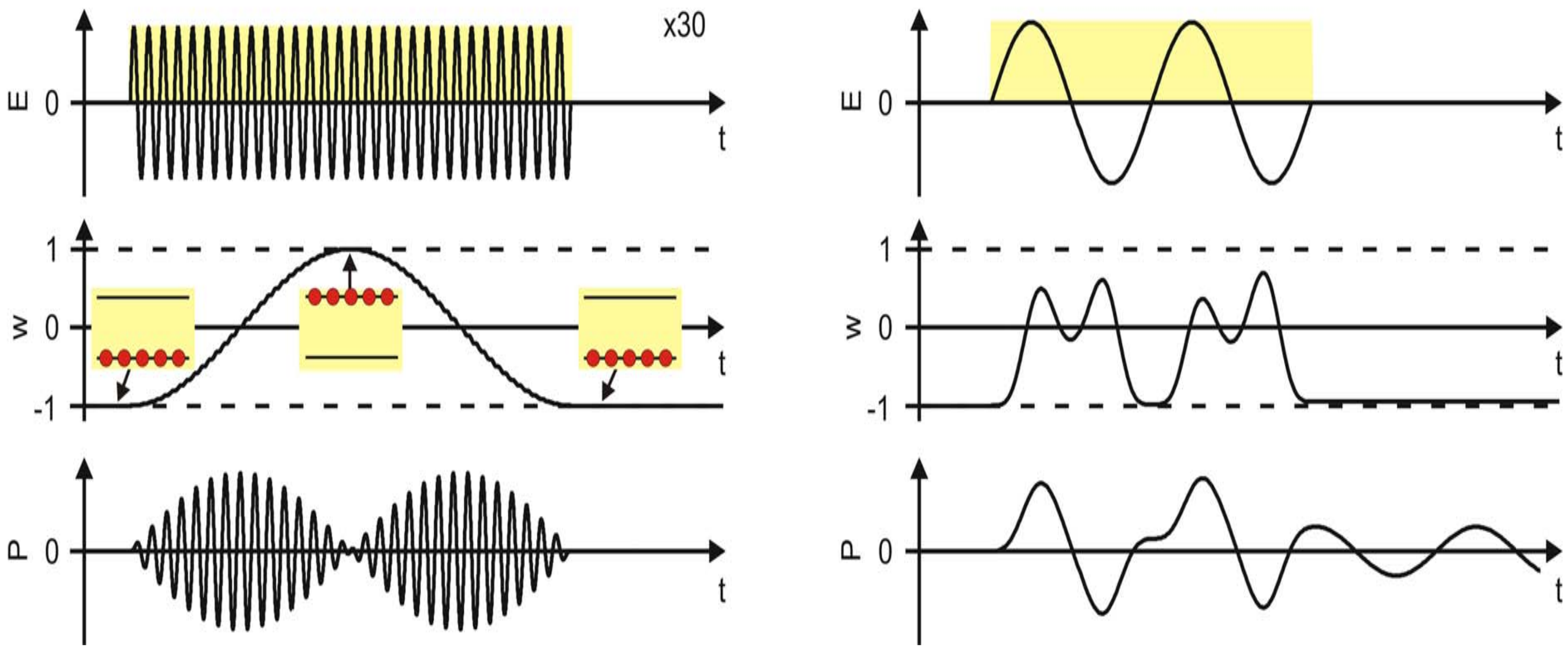
Homodyne Beat → Locked to Zero
600-1600 nm, → Single-Cycle Pulse


Newport

Carrier-Envelope Phase Detection

Hughes, PRL 81, pp. 3363 (1998), Carrier-Wave Rabi-Flopping

Conventional Rabi-Flopping | Carrier Wave - Rabi-Flopping

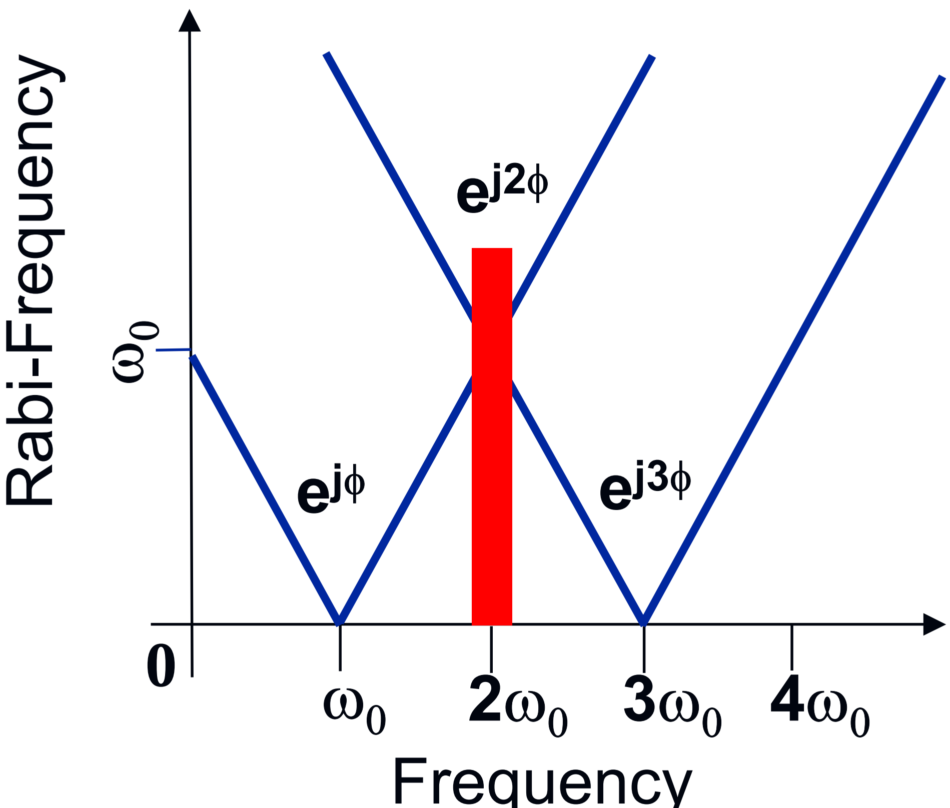


Mücke et al. PRL 87, 057401 (2001), Observation of Carrier-Wave Rabi-Flopping in GaAs

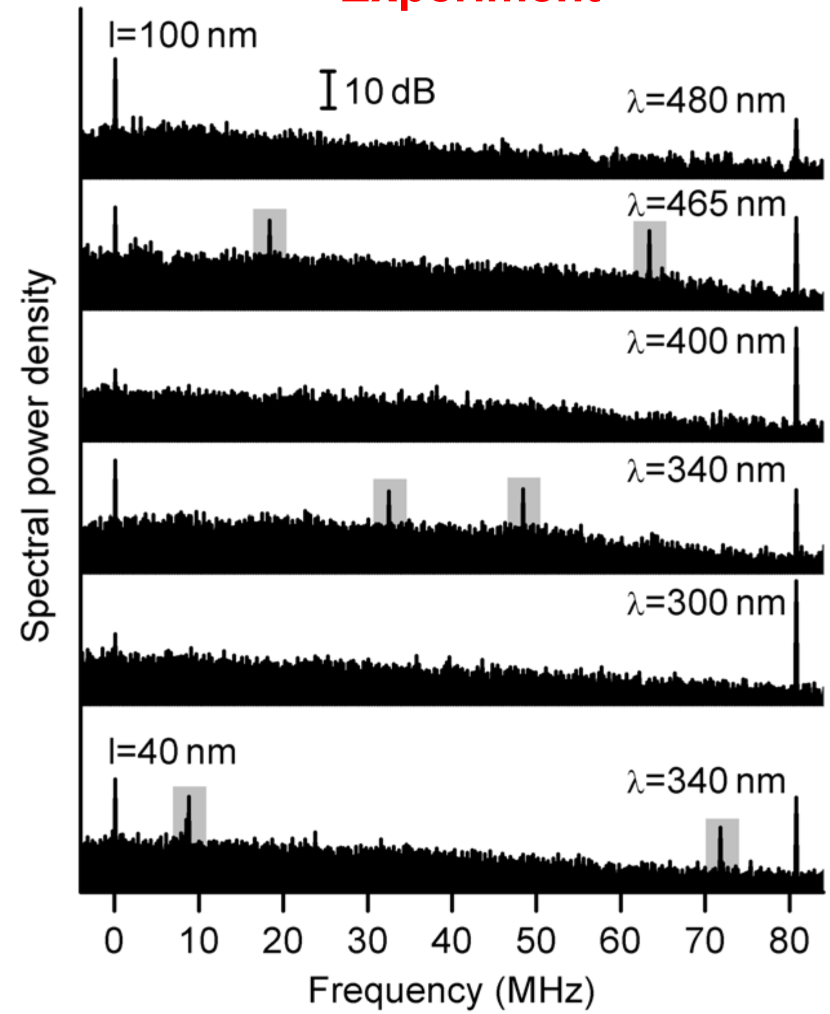
Break-Down of RWA

Mollow Sidebands and CE-Phase Detection

Mücke et al., PRL 89, 127401 (2002).
In cooperation with
Prof. Wegener, Karlsruhe University.



Experiment

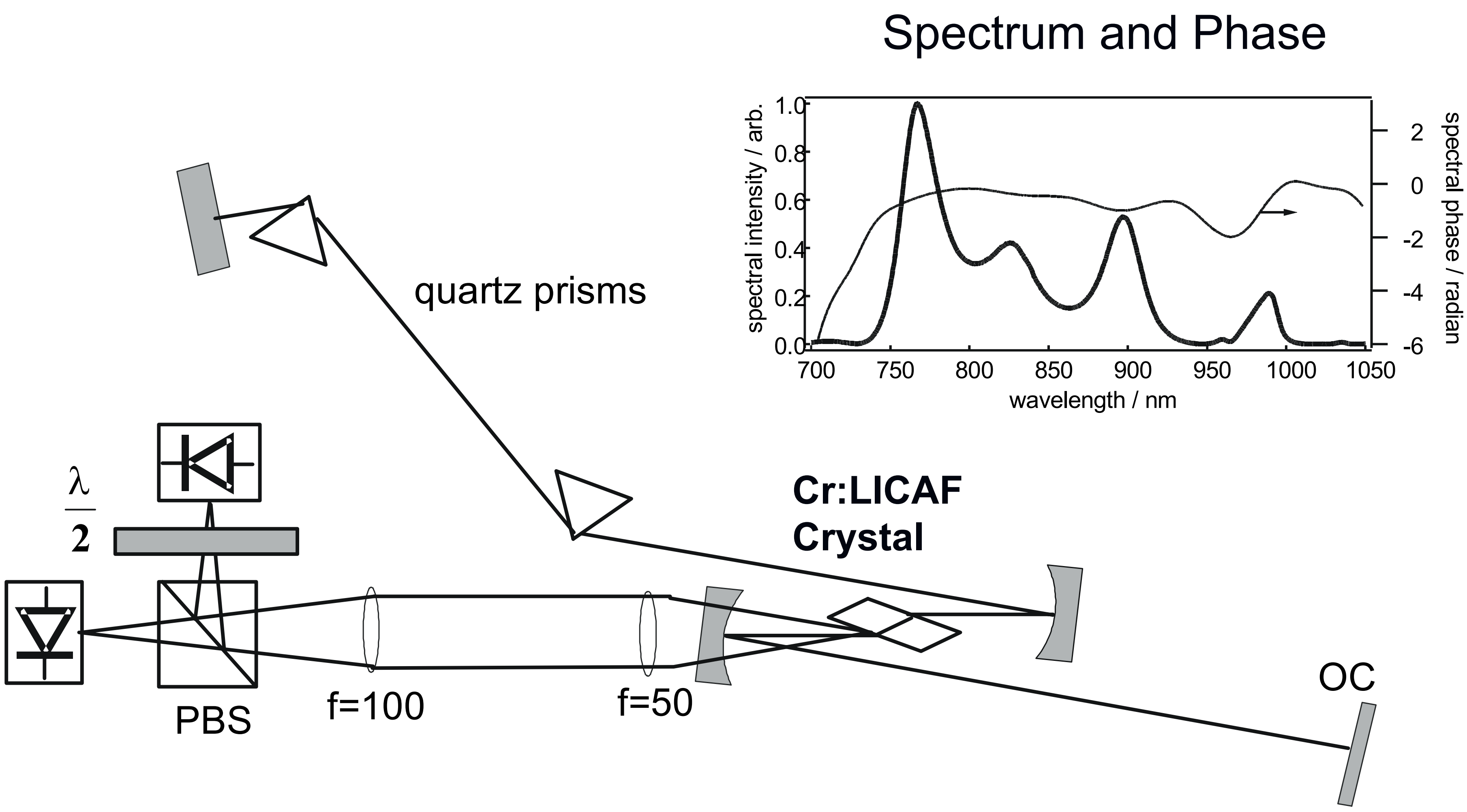


Or direct beat with SHG

Evtl. Electr. Detection of CE-Phase

Diode-pumped Cr:LiCAF Laser

(P. Wagenblast, Karlsruhe University, submitted to Optics Letters**)**



100MHz, 40mW, 9.6 fs

Conclusions

- Few-cycle laser pulse sources: Ti:sapphire, Cr:forsterite, Cr:YAG, Cr:LiCAF (diode-pumped)
- Octave spanning double-chirped mirror pairs
  -> 5 fs pulses directly from oscillators (1f-2f beat)
  -> Prismless, compact, long term stable version
- Extended frequency comb or single-cycle pulse synthesis
  -> 300 attosecond synchronization in 2.3 MHz bandwidth
  -> Difference carrier-envelope phase detection and stabilization.
- Future: Scaling to high repetition rates, comb characterization
  Improved broadband laser optics (Output Couplers, …)
  Electronic CE-phase detection (of above 10fs-pulses)
  -> Compact, diode-pumped stabilized combs