

**Distribution of an Ultrastable Frequency
Reference Using Optical Frequency Combs**

by

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Distribution of an Ultrastable Frequency Reference Using Optical Frequency Combs

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Frequency standards based on optical transitions in various atomic systems provide the potential for developing optical atomic clocks in the next few years that are several orders of magnitude more stable than the best existing clocks based on microwave-frequency references. The excellent stability that will be provided by optical clocks, and even the stability they currently offer, has applications in several fields, ranging from studies of fundamental physics to communication and remote synchronization. However, since optical clock systems are too complex to be portable, these applications rely on the ability to transfer over several kilometers a stable frequency reference that is linked to an optical clock. In this dissertation I present my research that enables the use of optical frequency combs from mode-locked lasers for transferring over optical fibers frequency references that are linked to optical standards.

This method of transfer requires that the optical frequency comb be stabilized to the optical standard. This is most easily accomplished by first stabilizing the comb from a mode-locked Ti:sapphire laser, which is described in detail. In particular, since intensity control of the laser is used for this stabilization, an analysis is presented on the intensity-related dynamics of the laser, enabling optimization of the control scheme. To minimize loss during transmission, it is necessary to transmit a 1550-nm comb instead of the 800-nm Ti:sapphire comb. Therefore, the stabilization of a 1550-nm mode-locked laser diode to the Ti:sapphire laser is discussed. This involves both the synchronization of the two lasers and the locking of their optical phases. The lowest reported timing jitter for a mode-locked laser diode is demonstrated.

Finally, measurements of the stability for transferring a microwave frequency over several kilometers of optical fiber using an optical frequency comb are presented. Without active stabilization, the comb provides an order of magnitude higher stability than is measured for existing methods of microwave-frequency transfer over fibers. With active cancellation of the transfer noise, the lowest timing jitter reported for the transfer of a frequency reference over several kilometers using optical fibers is achieved.

Dedication

To my father, Gary, who taught me the joy of understanding how things work.

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Contents

Chapter

1	Introduction to Optical Frequency Standards and Clocks	1
1.1	History of timekeeping: Interplay between science and clock technology	1
1.2	Redefining time	3
1.3	Motivations for precise timing	5
1.4	Optical frequency standards	8
1.5	Gears for optical atomic clock	11
1.6	Making optical frequency standards accessible: Frequency transfer . . .	13
2	Fundamentals of Stabilizing an Optical Frequency Comb	18
2.1	Free parameters of an optical frequency comb	18
2.2	Stabilization of carrier-envelope offset frequency	22
2.3	Stabilization of repetition frequency: Locking comb to optical or microwave standards	26
2.4	Transferring stability of one frequency comb to another	30
2.5	Characterization of frequency stability, phase noise, and timing jitter . .	33
3	Intensity-related Dynamics of a Ti:sapphire Laser	41
3.1	Theory of intensity-dependent mode-locking dynamics	42
3.2	Experimental investigation of intensity-related dynamics	45
3.3	Investigation of lineshape of carrier-envelope offset frequency	52

3.4	Conclusions	57
4	Experimental Results for Linking Optical and Microwave Frequencies with the Comb	60
4.1	Cell-based optical standard	61
4.2	Cold-atom-based optical standard	71
5	Transferring Ti:sapphire Frequency Comb Stability to a Mode-locked Laser Diode Comb	75
5.1	Synchronizing mode-locked laser diode to Ti:sapphire laser	76
5.2	Detecting mode-locked laser diode carrier-envelope offset frequency . . .	85
5.3	Orthogonal control of both mode-locked laser diode parameters	88
5.4	Conclusions	98
6	Stable Distribution of a Frequency Comb over Optical Fiber	100
6.1	Passive transfer of a frequency comb over optical fiber	102
6.2	Active noise cancellation with dispersion control for transfer of comb . .	115
6.3	Summary and future outlook for frequency transfer with combs	130
	Bibliography	136
	Appendix	
A	Derivation of Group Velocity with Kerr Nonlinearity	143
B	Single-side-band Generator	146

Tables

Table

6.1	Dependence of comb transfer stability on operating conditions	110
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Figures

Figure

2.1	Optical frequency comb from a mode-locked laser	20
2.2	Schematic for measuring f_{ceo}	24
2.3	Experimental setup for stabilizing f_{ceo}	25
2.4	Experimental setup for stabilizing f_{rep}	27
2.5	Stabilization of one frequency comb to another	31
2.6	Detection of timing jitter with optical cross-correlation	40
3.1	Setup to measure intensity-related dynamics of f_{rep} and f_{ceo}	46
3.2	Intensity dependence of laser spectrum and f_{ceo}	48
3.3	Response of f_{ceo} to intensity modulation near DC	49
3.4	Coefficients of intensity dependence for f_{rep} and f_{ceo} near DC	50
3.5	Dynamic response of f_{ceo} to intensity modulation	51
3.6	Intensity dependence of f_{ceo} spectral lineshape	53
3.7	Comparison of f_{ceo} linewidths for lasers with and without prisms	55
3.8	Dependence of f_{ceo} linewidth on pulse spectral width with prisms	56
3.9	Effect of pulse spectral width on f_{ceo} intensity response with prisms	57
4.1	Stability of measuring 515-nm I_2 transition using Cs-referenced comb	63
4.2	Absolute frequency measurement of 515-nm I_2 transition	64
4.3	Measurement of 532-nm I_2 transition with different comb systems	65

4.4	Stability of measuring 532-nm I ₂ transition using maser-referenced comb	67
4.5	Stability of f_{rep} when comb is stabilized to 532-nm I ₂ transition	69
4.6	I ₂ -system stability compared to mercury-ion-based optical standard . . .	70
4.7	Strontium energy level diagram	71
4.8	Absolute frequency measurement of ¹ S ₀ – ³ P ₁ transition of ⁸⁸ Sr	73
5.1	Schematic of mode-locked laser diode	77
5.2	Stabilization of MLLD f_{rep} using wide-bandwidth current feedback . . .	79
5.3	Effect of wide-bandwidth current feedback on MLLD f_{rep} linewidth . . .	81
5.4	Residual timing jitter of MLLD with current feedback	82
5.5	Stability of MLLD f_{rep} with feedback	85
5.6	Detection of MLLD f_{ceo} fluctuations	87
5.7	Dependence of MLLD f_{rep} and f_{ceo} on its control variables	90
5.8	Stabilization of MLLD f_{rep} and f_{ceo} using orthogonal control	92
5.9	Effect of orthogonal control loop on MLLD f_{rep}	94
5.10	Effect of orthogonal control loop on MLLD f_{ceo} linewidth	95
5.11	Stability of MLLD f_{ceo} using orthogonal control loop	97
6.1	Schematic of mode-locked fiber laser	103
6.2	Setup for measuring transfer instability for comb repetition frequency .	105
6.3	Instability for microwave-frequency transfer with comb	108
6.4	Dependence of transfer stability on mode-locked laser parameters	111
6.5	Effect of EDFA on microwave-frequency transfer stability	112
6.6	Effect of EDFA on timing jitter for comb transfer	114
6.7	Measured GDD of BRAN and dispersion-compensation fiber	118
6.8	Active cancellation of noise for microwave-frequency transfer using comb	120
6.9	Adjustable delay line for cancellation of transfer noise	121
6.10	Frequency stability for transfer with active noise cancellation	122

6.11	Timing jitter for transfer with active noise cancellation	124
6.12	Transfer timing jitter with faster PZT-actuated fiber stretcher	129
B.1	Schematic of single-side-band generator	147
B.2	Output of single-side-band generator	150