Yoon-Soo Jang, Ph. D.

Senior Research Scientist
Center for Optical Metrology, Division of Physical Metrology
Korea Research Institute of Standards and Science (KRISS)

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Research Interests

Frequency comb based optical metrology including LiDAR, absolute distance measurement (ADM), extremely small displacement measurement, ultra-fast phenomena and precision spectroscopy. Also, developing the ultra-stable light sources including Kerr comb generation from microresonator, microcavity based stabilization of laser frequency, Er-doped fiber femtosecond oscillator, optical frequency comb, space-qualified femtosecond laser and time/frequency transfer.

Education

Korea Advanced Institute of Science and Technology (KAIST), Daejeon, KOREA
Ph.D. of Mechanical Engineering, 2013-2017. (GPA: 4.02/4.3)

Thesis: Ultraprecision measurement of absolute distances in air using frequency comb referenced multi-wavelength interferometer.

Advisor: Prof. Seung-Woo Kim

Korea Advanced Institute of Science and Technology (KAIST), Daejeon, KOREA
Master of Science in Mechanical Engineering, 2011-2013. (GPA: 4.05/4.3)

Thesis: Space radiation test of critical optical components and space-borne fiber femtosecond laser.

Advisor: Prof. Seung-Woo Kim

INHA University, Incheon, KOREA
Bachelor of Science in Mechanical Engineering, 2007-2011. (GPA: 4.27/4.5)

Advisor: Prof. Kwang-Yong Kim

Employment

Center for Optical Metrology, Division of Physical Metrology
Korea Research Institute of Standards and Science (KRISS)

Senior Research Scientist (May. 2019 – present)

Mesoscopic Optics and Quantum Electronics Laboratory
Department of Electrical and Computer Engineering, UCLA

Postdoctoral Research Scientist (Mar. 2018 – May. 2019) Advisor: Prof. Chee Wei Wong

Precision Engineering and Metrology Lab
Ultrafast Optics for Ultra-precision Group, Department of Mechanical Engineering, KAIST

Postdoctoral researcher (Aug. 2017 – Mar. 2018) Advisor: Prof. Seung-Woo Kim
Graduate student (Feb. 2011 – Aug. 2017) Advisor: Prof. Seung-Woo Kim

Peer Reviewed Journal Publications

(†: co-first author, *: Corresponding author)

1. **Y.-S. Jang**, J. Lee, S. Kim, K. Lee, S. Han, Y.-J. Kim, and S.-W. Kim*, "Space radiation test of saturable absorber for femtosecond laser," *Optics Letters* **39**(10), 2831-2834 (2014). IF: 3.179, Citation: 10 (GS), 3 (WOS)

2. J. Lee†, K. Lee†, **Y.-S. Jang**, H. Jang, S. Han, S.-H. Lee, K.-I. Kang, C.-W. Lim, Y.-J. Kim and S.-W. Kim*, "Testing of a femtosecond pulse laser in outer space," *Scientific Reports* **4**, 5134 (2014). IF: 5.078 Citation: 68 (GS)

3. **Y.-S. Jang**, K. Lee, S. Han, J. Lee, Y.-J. Kim and S.-W. Kim*, "Absolute distance measurement with extension of nonambiguity range using the frequency comb of a femtosecond laser," *Optical Engineering* **53**(12), 122403 (2014). IF: 0.958, Citation: 27 (GS)

4. G. Wang†, **Y.-S. Jang† (equally contributed 1st author)**, S. Hyun, B. J. Chun, H. J. Kang, S. Yan, Y.-J. Kim, S.-W. Kim*, "Absolute positioning by multi-wavelength interferometry referenced to the frequency comb of a femtosecond laser," *Optics Express* **23**(7), 9121-9129. (2015). IF: 3.525, Citation: 33 (GS)

5. H. Jang, **Y.-S. Jang**, S. Kim, K. Lee, S. Han, Y.-J. Kim, and S.-W. Kim*, "Polarization maintaining linear cavity Er-doped fiber femtosecond laser," *Laser Physics Letters* **12**(10), 105102. (2015). IF: 2.458, Citation: 14(GS)

6. H. J. Kang, B. J. Chun, **Y.-S. Jang**, Y.-J. Kim, and S.-W. Kim*, "Real-time compensation of the refractive index of air in distance measurement," *Optics Express* **23**(10), 26377-36385. (2015). IF: 3.488, Citation: 22 (GS)

7. K. Lee, J. Lee, **Y.-S. Jang**, S. Han, H. Jang, Y.-J. Kim, and S.-W. Kim*, "Fourier-transform spectroscopy using Er-doped fiber femtosecond laser by sweeping the pulse repetition rate," *Scientific Reports* **5**, 15726. (2015). IF: 5.078, Citation: 18 (GS)

8. **Y.-S. Jang**, G. Wang, S. Hyun, B. J. Chun, H. J. Kang, Y.-J. Kim, and S.-W. Kim*, "Comb-referenced laser distance interferometer for industrial nanotechnology," *Scientific Reports* **6**, 31770. (2016). IF: 5.078, Citation: 15 (GS)

9. **Y.-S. Jang**, and S.-W. Kim*, "Compensation of the refractive index of air in laser interferometer for distance measurement: a review," *International Journal of Precision Engineering and Manufacturing* **18**(12), 1881-1890. (2017). IF: 1.497, Citation: 26 (GS)

10. **Y.-S. Jang,** W.-R. Kim, H. Jang, and S.-W. Kim*, "Absolute distance meter operating on a free-running mode-locked laser for space mission," *International Journal of Precision Engineering and Manufacturing* **19**(7), 975-981. (2018). IF: 1.497, Citation: 5 (GS)

11. **Y.-S. Jang**, and S.-W. Kim*, "Distance measurements using mode-locked lasers: A review," *Nanomanufacturing and Metrology* **1**(3), 131-147. (2018), Citation: 13 (GS)

12. H. Jang, B.-S. Kim, B. J. Chun, H. J. Kang, **Y.-S. Jang**, Y.-J. Kim and S.-W. Kim*, "Comb-rooted multi-

channel synthesis of ultra-narrow optical frequencies of few Hz linewidth," *Scientific Reports* **9**, 7652. (2019). IF: 4.011, Citation: 1 (GS)

(Submitted)

13. J. Park, H. Mori, **Y.-S. Jang**, and J. Jin*, "Precise thickness profile measurement insensitive to spatial and temporal temperature gradients on a large glass substrate," *Applied Optics*, accepted for publication (2020).

14. **Y.-S. Jang***, H. Liu, J. Yang, M. Yu, D.-L. Kwong, and C. W. Wong*, "Nanometirc precision distance meatrology via chip-scale frequency microcombs," *Physical Review Letters*, in revision (2020).

15. J. Park, J. Bae, **Y.-S. Jang**, and J. Jin*, "Simultaneous measurement of thickness, refractive index, bow and warp of a large silicon wafer using a spectral-domain interferometer," *Metrologia*, in revision (2020).

16. W. Wang†*, H. Liu†*, J. Yang, A. K. Vinod, J. Lim, **Y.-S. Jang**, H. Zhou, M. Yu, D.-L. Kwong, P. DeVore, J. Chou*, and C. W. Wong*, "Mapping few-femtosecond jitter in 88 GHz mode-locked laser frequency microcombs via linear interferometry," *Laser & Photonics Reviews*, submitted (2020).

17. **Y.-S. Jang†***, J. Lim†, W. Wang, S.-W. Kim, W. Liang, A. B. Matsko, L. Maleki, and C. W. Wong*, "Sub-fm/Hz$^{1/2}$ displacement spectral densities in an ultrahigh-Q whispering gallery mode optical microcavity," *Optica*, submitted (2020).

(In preparation)

18. **Y.-S. Jang†*,** W.-R. Kim†, H. Fu, S. Han, K. Lee, and S.-W. Kim*, "Systematic error analysis and correction in distance measurement using femtosecond mode-locked laser [invited]," *Applied Physics*, in preparation (2020).

19. **Y.-S. Jang***, J. Flor Flores, W. Wang and C. W. Wong*, "Ultrastable laser interferometer for long distance sound sensing," in preparation (2020).

20. **Y.-S. Jang,** J. Park, and J. Jin, "100-nm precision laser ranging toward on-chip LIDAR," in preparation (2020).

GS: Google scholar.

Book Chapter

1. **Y.-S. Jang,** and S.-W. Kim, ""Distance measurements using mode-locked pulse lasers," *Modern Interferometry for Length Metrology: Exploring Limits and Novel Techniques, (Book Chapter, IOPscience)*, (2018).

2. **Y.-S. Jang**, S. Han, J. Park, and S.-W. Kim, "Dimensional metrology using mode-locked lasers," *Precision Manufacturing, (Book Chapter, Springer)*, (2019)

Conference Proceedings and Presentation

(International)

1. S.-W. Kim, Y.-J. Kim, J. Lee, K. Lee, S. Han, **Y.-S. Jang** and H. Jang, "Precision Metrology for Space Missions using Femtosecond Laser Pulses," in *4-th Asian Society for Precision Engineering and Nanotechnology (ASPEN 2011)*, 2011.11.

2. Y.-J. Kim, K. Lee, S. Han, **Y.-S. Jang**, H. Jang and S.-W. Kim, "Development of fiber femtosecond

lasers for advanced metrological space missions," in *The conference on Lasers and Electro-Optics Pacific Rim (CLEO-PR 2013)*, (Optical Society of America, 2013), paper WF_33, 2013.06.

3. **Y.-S. Jang**, S. Kim, J. Lee, K. Lee, S. Han, S.-W. Kim and Y.-J. Kim, "Space radiation effects on a semiconductor saturable absorber," in *The conference on Lasers and Electro-Optics Pacific Rim (CLEO-PR 2013)*, (Optical Society of America, 2013). paper WPF_35, 2013.06.

4. Y.-J. Kim, J. Lee, K. Lee, S. Han, **Y.-S. Jang**, H. Jang and S.-W. Kim, "Ultra-precision LIDAR System using Femtosecond Light Pulses," in *Advanced Photonic Congress*, (Optical Society of America, 2013). paper SW4B.1, 2013.07.

5. S.-W. Kim, Y.-J. Kim, S. Hyun, B. J. Chun and **Y.-S. Jang**, "Recent advances in absolute distance measurements using femtosecond light pulses," in *9-th International Symposium on Precision Engineering Measurements and Instrumentation (ISPEMI 2014)*, 2014.08.

6. G. Wang, **Y.-S. Jang**, H. J. Kang, B. J. Chun, Y.-J. Kim, and S.-W. Kim, "Absolute distance measurement using frequency-comb-referenced four-wavelength interferometry," in *9-th International Symposium on Precision Engineering Measurements and Instrumentation (ISPEMI 2014)*, 2014.08.

7. H. J. Kang, B. J. Chun, **Y.-S. Jang**, Y.-J. Kim, and S.-W. Kim, "Real-time monitoring of air refractive index for absolute distance measurement," in *The 6th International Conference on Positioning Technology (ICPT 2014)*, 2014.11.

8. S.-W. Kim, Y.-J. Kim, B. J. Chun, K. Lee, S. Han, and **Y.-S. Jang**, "Advanced optical distance measurements using femtosecond laser pulses," in *The conference on Lasers and Electro-Optics (CLEO 2015)*, (Optical Society of America, 2015), 2015.05.

9. H. J. Kang, B. J. Chun, **Y.-S. Jang**, Y.-J. Kim and S.-W. Kim, “Two-color interferometer for real-time compensation of air refractive index,” in *ASPEN 2015*, 2015.08.

10. **Y.-S. Jang**, G. Wang, S. Hyun, H. J. Kang, B. J. Chun, Y.-J. Kim and S.-W. Kim, “Absolute distance interferometer with nanometer uncertainty,” in *The 7th International Conference on Positioning Technology (ICPT 2016)*, 2016.11.

11. **Y.-S. Jang**, G. Wang, H. J. Kang, Y.-J. Kim and S.-W. Kim, “Absolute distance measurement using comb referenced multi-wavelength interferometer,” in *The 7th International Conference of Asian Society for Precision Engineering and Nanotechnology (ASPEN 2017)*, 2017.11.

12. J. Lim, A. Savnchenkov, **Y.-S. Jang**, A. Matsko, and Chee Wei Wong, "A sub-10 μK, dual-mode temperature stabilized microresonator," in *The conference on Lasers and Electro-Optics (CLEO 2019)*, (Optical Society of America, 2019), paper SF2H.6, 2019.05.

13. **Y.-S. Jang**, J. Lim, S.-W. Kim, W. Liang, A. B. Matsko, L. Maleki, and Chee Wei Wong, "Achieving sub-femtometer displacement sensitivity in integrated ultrahigh-Qcrystalline microcavities via Pound-Drever-Hall," in *The conference on Lasers and Electro-Optics (CLEO 2019)*, (Optical Society of America, 2019), paper STh4G.4 2019.05.

14. **(Invited)** C. W. Wong, W. Wang, J. Yang, **Y.-S. Jang**, and H. Liu, "Ultrafast mode-locked frequency microcombs: fundamentals and precision metrology," in *Photonics West (Ultrafast phenomena and nanophotonics)*, (SPIE, 2020), 2020.02.

15. **Y.-S. Jang**, J. Lim, S.-W. Kim, A. Savchenkov, A. B. Matsko, and Chee Wei Wong, " Sub-fm/$Hz^{1/2}$ displacement measurement on MgF2 whispering gallery mode microcavity," in *The conference on Lasers and Electro-Optics (CLEO 2020)*, (Optical Society of America, 2020), 2020.05.

(Domestic)

1. 주우덕, 김영진, 김윤석, 박지용, **장윤수**, 김승우, "펨토초 펄스 레이저를 이용한 대면적 형상측정 간섭계 (Interferometry for precision large-surface profile measurement using femtosecond pulse laser)," 한국정밀공학회 춘계학술대회(Korean Society of Precision Engineering Autumn Conference), (2011.06)
2. 이주형, 김영진, 이근우, 이상현, 한성흠, **장윤수**, 장희숙, 오대수, 김승우, "나로과학위성 탑재를 위한 펨토초 레이저 탑재체 개발(Development of fiber femtosecond oscillator (FSO) payload for Naro science satellite)," 한국광학회 2012년도 하계학술발표회(Optical Society of KOREA Summer Conference), (2012.08)
3. 김영진, 이근우, 한성흠, **장윤수**, 장희숙, 김승만, 이상현, 이주형, "우주임무를 위한 펨토초 레이저 기반 초정밀 측정기술(High-precision Metrology for Space Missions using Femtosecond Lasers)," 한국광학회 2013년도 동계학술발표회(Optical Society of KOREA Winter Conference), (2013.02)
4. **장윤수**, 김승만, 이근우, 한성흠, 김영진, 김승우, 이주형, "광섬유 펨토초 레이저 및 포화흡수체의 우주 방사선 환경평가(Space radiation test of a saturable absorber and a fiber femtosecond laser)," 한국광학회 2013년도 동계학술발표회(Optical Society of KOREA Winter Conference), (2013.02)
5. 이주형, 김영진, 이상현, 이근우, 김승만, 한성흠, **장윤수**, 장희숙, 오대수, 강경인, 김승우, "우주프로젝트를 위한 초정밀 광계측(Precision optical metrology for space mission)," 한국생산제조시스템학회 2013년도 춘계학술대회(Spring Conference of the Korean Society of Manufacturing Technology Engineers), (2013.04)
6. 이근우, **장윤수**, 한성흠, 장희숙, 김영진, 김승우, "펨토초 레이저 광 빗을 이용한 높은 정밀도의 합성파 간섭계 기반의 절대거리 측정(Absolute distance measurement based on high precision synthetic wavelength interferometer with femtosecond frequency comb)," 항공우주시스템공학회 2013년도 춘계학술대회(Proceedings of SASE(The Society of Aerospace System Engineering) Spring Conference), (2013.05)
7. 장희숙, **장윤수**, 이근우, 한성흠, 김영진, 김승우, 이주형 "우주 적용을 위한 고신뢰성 편광 유지 광섬유 기반 펨토초 레이저 통합 시스템 (High reliable polarization maintaining fiber femtosecond laser system for space application)," 한국광학회 2014 하계학술발표회(Optical Society of KOREA Summer Conference), (2014.08)
8. 강현재, 천병재, **장윤수**, 김영진, 김승우, "대기 중 정밀 거리 측정을 위한 광빗 기반 두 파장 간섭계 (Comb-referenced two-color interferometry for high-precision ranging in air)," 한국정밀공학회 2014 추계학술대회(Korean Society of Precision Engineering Autumn Conference), (2014.

10)

9. 이근우, **장윤수**, 한성흠, 장희숙, 김승우, 이주형, 김영진, “펨토초 레이저를 이용한 광대역 퓨리에 분광 기술 (Broadband Fourier transform spectroscopy using femtosecond laser,” 한국광학회 2015 하계 학술발표회 (Optical Society of KOREA Summer Conference), (2015.07)

10. 이근우, **장윤수**, 한성흠, 장희숙, 김승우, “절대거리 측정을 위한 소형화된 펨토초 레이저 기반 합성파 간섭계 개발(Femtosecond laser based compact synthetic wavelength interferometer for absolute distance measurement),” 한국생산제조시스템학회 2015년도 추계학술대회(Autumn Conference of the Korean Society of Manufacturing Technology Engineers), (2015.10)

11. **장윤수**, 한성흠, 이근우, 장희숙, 김승우, “절대거리 측정을 위한 펨토초 레이저 기반 합성파 간섭계(Femtosecond laser based synthetic wavelength interferometer for absolute distance measurement),” 한국정밀공학회 2015 추계학술대회(Korean Society of Precision Engineering Autumn Conference), (2015.12)

12. **장윤수,** 강현재, Wang Guochao, 현상원, 천병재, 김영진, 김승우, “초정밀절대거리 측정을 위한 광 빗 기반 다파장 간섭계(Precise absolute distance measurement by frequency comb referenced multi-wavelength interferometer),” 한국정밀공학회 2015 추계학술대회(Korean Society of Precision Engineering Autumn Conference), (2015.12)

13. 김승만, 오정석, 이근우, 한성흠, **장윤수**, 김승우, “3차원 공간좌표측정을 위한 레이저 트랙킹 기반 다중 절대거리측량 (Multiple absolute distance measurements based on laser tracking for 3D coordinate)” 한국생산제조시스템학회 2016년도 춘계학술대회(Spring Conference of the Korean Society of Manufacturing Technology Engineers), (2016.04)

14. 이근우, 한성흠, **장윤수**, 김우람, 김승우, “펨토초 레이저를 이용한 다중 절대거리 측정 장치의 개발 및 적용(Development of multi-target distance meter using femtosecond lasers),” 한국생산제조시스템학회 2016년도 추계학술대회 (Autumn Conference of the Korean Society of Manufacturing Technology Engineers). (2016.11)

15. 김우람, **장윤수**, 김승우, “펨토초 레이저 기반 합성파 간섭계의 비선형 오차 보상 (Nonlinear error correction in femtosecond laser based synthetic wavelength interferometer),” 한국정밀공학회 2017 추계학술대회(Korean Society of Precision Engineering Autumn Conference), (2017.12)

Patents

1. 김승우, 진종한, 이주형, 김영진, 김윤석, 이근우, 한성흠, **장윤수**, 장희숙, "펨토초 레이저 기반의 위상 잠금 합성파 간섭계를 이용한 거리 측정 장치 (Distance measuring apparatus using phase-locked synthetic wavelength interferometer based on femtosecond laser)," Patent number: 10-1448831, 2014.10. (KOREA)

2. 김승우, 한성흠, **장윤수**, 이근우, 장희숙, "프리러닝 펨토초 레이저 기반의 실시간 합성파 결정을 이용한 거리측정 장치 (Distance measuring apparatus using real time determination of synthetic wavelength based on free running femtosecond laser)," Patent number: 10-1684269, 2016.12. (KOREA)
3. 김승우, 강현재, 천병재, 김영진, **장윤수**, "펨토초 레이저 광빗 기반 두 파장 간섭계를 이용한 거리 및 굴절률 측정 방법 및 장치 (Method and apparatus for monitoring distance and refractive index using two-color interferometer based on optical comb of femtosecond laser)," Patent number: 10-1462952, 2016.07. (KOREA)
4. 김승우, **장윤수**, 강현재, 한성흠, "다중 두파장 간섭계를 이용한 공기 굴절률 보상 장치 (Air refractive index compensating apparatus using multi-two color interferometer based on optical frequency comb)," Patent number: 10-1746693, 2017.06. (KOREA)
5. 김승우, 장희숙, 김영진, **장윤수**, "장기간 안정성을 갖는 포화흡수체 기반의 전-편광 유지 광섬유 레이저 (All-fiber polarization maintaining oscillator for long-term operation)," Patent number: 10-1832424, 2018.02. (KOREA)
6. 김승우, **장윤수**, 김병수, "PDH 잠금 기법을 이용한 초미세 변위 측정 장치 및 방법," Patent number: 10-2088501, 2020.03. (KOREA)
7. 김승우, **장윤수**, 김우람, "동일 광경로 간섭계를 통한 펄스 레이저 특성에 따른 군 굴절률 측정 방법 및 장치," (출원중, KOREA)
8. **Yoon-Soo Jang**, Chee Wei Wong, Hao Liu, "CHIP-SCALE FREQUENCY-COMB ASSISTAED COHERENT LIDAR RANGING WITH SUB-MICROMETER PRECISION," (Submitted, USA)
9. **Yoon-Soo Jang**, Chee Wei Wong, Hao Liu, "Chip-scale frequency-comb assisted broadband scanning spectroscopy for standoff and point-sampling trace chemical detection," (in preparation, USA)

Professional Activities and Achievements

- 2014 재단법인 우덕윤덕병 재단 장학생
  Scholarship student of Woodeok Yoon Deok Byoung Foundation (5,000,000 KRW), 2014.
- 2018년도 한국과학기술원 기계공학과우수상, 박사부문, 기계동문회장상
  Ph.D. Excellence Award from Dept. of Mech. Eng., KAIST 2018.
- Full member of **Optical Society of Korea (OSK), Optical Society of America (OSA) and Korea Society for Precision Engineering (KSPE)**.
- Reviewer of **Applied Optics (OSA), International Journal of Precision Engineering and Manufacturing (Springer, KSPE), Laser Physics Letters (IOPscience)**.

Research Experience

Ultra-precision optical metrology;

- (Distance metrology) Chip-scale sub-μm laser ranging using microresonator based Kerr frequency comb.

- (Distance metrology) State-of-art high precision absolute distance metrology using frequency-comb-referenced multi-wavelength interferometer (MWI).
- (Distance metrology) Real-time monitoring and self-correction of air refractive index for absolute distance measurement.
- (Distance metrology) Extremely small displacement measurement with high speed data acquisition for thermal noise of optical cavity and mechanical vibration motion.
- (Distance metrology) Compact absolute distance meter using synthetic wavelength interferometer for formation flying of satellites and mobile machining platform.
- (Pump-probe measurement) Observation of ultra-fast phenomena of optical materials.
- (Spectroscopy) Femtosecond laser based Fourier-transform spectroscopy for broadband LIDAR.

Ultrafast light sources;

- Hybrid mode-locked Er-doped fiber femtosecond oscillator (pulse width: < 150 fs, repetition rate: 50 MHz, optical power: > 100 mW, spectral bandwidth: > 30 nm).
- Frequency comb stabilization to atomic time standard by self-referencing *f*-2*f* interferometer and PLL technique.
- Ultra-stable optical frequency generation referenced to the optical frequency comb. (relative stability: < 10^{-15})
- Space qualified fiber femtosecond oscillator insensitive to vibration and space radiations.
- Super-continuum generation using femtosecond frequency comb for broad-band spectroscopic LIDAR.