



# AIC: Activity report

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# WG structure and operation

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- loose group structure
  - meet once or twice per year for overview (no telecons)
  - plus about one/two per year special topic meetings
    - next ones: QND meeting and Simulation/Software tools meeting, both satellites of the next LV meeting Hannover
- concerned with generic configurations
  - individual components → Optics WG
  - sensing for Advanced LIGO → ISC (recent)
- close link to 40m program via TAC
- web page / email list
  - now use LSC email based list (otherwise unmanageable)
  - requires input to ensure new members are added when necessary
  - people who fall off attachments Z will automatically be removed (as they lose their ligo.org email)

## Recent work

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- DC readout (40m) → ELi & AdL
- New AdL ISC (40m + others) → AdL
- Squeezing (MIT/40m/AEI/ANU)
  - wideband low-noise (down to GW band)
  - stronger squeezing
  - noise reduction at 40m
- Simulation/Sensing methods (40m/AEI/ANU/Glasgow/MIT/TAMA/UF)
  - optickle, finesse, FFT, e2e, ...
  - developing code and/or application
- Theory (MSU/CIT/AEI)
  - QND schemes, ponderomotive squeezing, intracavity readout, control in QND systems



## Recent papers - LSC reviewed (31)

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- Barr, BW; et al. *Control Sideband Generation for Dual-Recycled Laser Interferometric Gravitational-Wave Detectors*
- Barr, BW; et al. *Optical Modulation Techniques for Length Sensing and Control of Optical Cavities*
- Beyersdorf, PT *Input Spectrum for Heterodyne Detection in Advanced Gravitational Wave Detectors Without Non-Stationary Shot-Noise*
- Bunkowski, A; Burmeister, O; Friedrich, D; Danzmann, K; Schnabel, R *High Reflectivity Grating Waveguide Coating for 1064 nm*
- Chelkowski, S; Vahlbruch, H; Danzmann, K; Schnabel, R *Coherent Control of Broadband Vacuum Squeezing*
- Corbitt, T; Chen, Y; Mavalvala, N *Mathematical Framework for Simulation of Quantum Fields in Complex Interferometers Using the Two-Photon Formalism*
- Corbitt, T; Chen, Y; Khalili, F; Ottaway, D; Vyatchanin, S et al. *A Ponderomotively Squeezed Source for Advanced Gravitational-Wave Interferometers*

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- Corbitt, T; Ottaway, D; Innerhofer, E; Pelc, J; Mavalvala, N  
*Measurement of Radiation-pressure-induced Optomechanical Dynamics in a Suspended Fabry-Perot Cavity*
  - Danilishin, S; Khalili, F *To the Practical Design of the Optical Lever Intracavity Topology of GW Detectors*
  - Goda, K; Miyakawa, O; Mikhailov, EE; Saraf, S; Adhikari, R et al.  
*Quantum Enhancement in a Prototype Gravitational Wave Detector*
  - Hild, S; Grote, H; Hewitson, M; Lueck, H; Smith, JR et al.  
*Demonstration and Comparison of Tuned and Detuned Signal Recycling in a Large-Scale GW Detector*
  - Hild, S; Freise, A *A Novel Concept for Increasing the Peak Sensitivity of Initial LIGO by Detuning the Arm Cavities*
  - Huttner, SH; Barr, BW; Plissi, MV; Taylor, JR; Sorazu, B et al.  
*Novel Sensing and Control Schemes for a Three Mirror Coupled Cavity*

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- Khalili, F      *Increasing Future Gravitational-Wave Detectors Sensitivity by Means of Amplitude Filter Cavities and Quantum Entanglement*
  - Khalili, FY      *Quantum Variational Measurement and the "Optical Lever" Intracavity Topology of Gravitational-Wave Detectors*
  - Khalili, FY; Lazebny, VI; Vyatchanin, SP      *Sub-SQL Sensitivity via Optical Rigidity in Advanced LIGO Interferometer with Optical Losses*
  - Khalili, FY      *Quantum Variational Measurement in the Next generation Gravitational-Wave Detectors*
  - McKenzie, K; Mikhailov, E; Goda, K; Koy Lam, P; Grosse, N et al.      *Quantum Noise Locking*
  - Mikhailov, E; Goda, K; Corbitt, T; Mavalvala, N      *Frequency-Dependent Squeeze Amplitude Attenuation and Squeeze Angle Rotation by Electromagnetically Induced Transparency for Gravitational Wave Interferometers*

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- Mikhailov, E; Goda, K; Mavalvala, N      *Non-invasive Measurements of Cavity Parameters by Use of Squeezed Vacuum*
  - Miyakawa, O; Ward, R; Adhikari, R; Evans, M; Abbott, B et al.  
*Measurement of Optical Response of a Detuned Resonant Sideband Extraction Interferometer*
  - Mueller-Ebhardt, H; Rehbein, H; Schnabel, R; Danzmann, K; Chen, Y  
*Entanglement of Suspended Test Masses in Michelson Laser Interferometers in Advanced LIGO Interferometer with Optical Losses*
  - Rabeling, DS; Gossler, S; Cumpston, J; Gray, MB; McClelland, DE    A  
*"New" Topology for the Control of Complex Interferometers*
  - Rehbein, H; Mueller-Ebhardt, H; Somiya, K; Li, C; Schnabel, R et al.  
*Local Readout Enhancement for Detuned Signal-Recycling Interferometers*
  - Sato, S; Kawamura, S; Kokeyama, K; Kawazoe, F      *Diagonalization of the Length Sensing Matrix of a Dual Recycled Laser Interferometer Gravitational Wave Antenna*

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- Sato, S; Kokeyama, K; Ward, RL; Kawamura, S; Chen, Y et al.  
*Demonstration of Displacement- and Frequency-Noise Free Laser Interferometry Using Bi-Directional Mach-Zehnder Interferometers*
  - Thuring, A; Schnabel, R; Lueck, H; Danzmann, K *Detuned Dual-Recycling for Ultra-High Precision Interferometers*
  - Vahlbruch, H; Chelkowski, S; Hage, B; Franzen, A; Danzmann, K et al.  
*Demonstration of a Squeezed Light Enhanced Power- and Signal-Recycled Michelson Interferometer*
  - Vahlbruch, H; Chelkowski, S; Hage, B; Franzen, A; Danzmann, K et al.  
*Coherent Control of Vacuum Squeezing in the Gravitational-Wave Detection Band*
  - Vahlbruch, H; Mehmet, M; Lastzka, N; Hage, B; Chelkowski, S et al.  
*Observation of Squeezed Light with 10 dB Quantum Noise Reduction*
  - Wise, S; Quetschke, V; Deshpande, AJ; Mueller, G; Reitze, DH et al. *On the Phase of Light Diffraction by Gratings*



# Future priorities

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- Looking to the future
  - we believe there are applications for
    - high power / wide band interferometers
    - low power / QND interferometers (e.g. to work with cryo)
- Areas of research include the following:
  - configurations with diffractive couplers and beamsplitters
  - configurations with various types of squeezing and associated readout techniques (variational etc.)
  - intracavity readout configurations (optical levers) and their associated readout meters

# Conclusion

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- Considering the long term goals the AIC structure is probably adequate
- AdL has made clear the long lead-time needed to prepare techniques ready for implementation (~decade)
  - R&D for 3<sup>rd</sup> generation detector technology is relatively urgent