

# PROCEEDINGS OF SPIE

## ***Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy IX***

**Jonas Zmuidzinas  
Jian-Rong Gao**  
*Editors*

**12–15 June 2018  
Austin, Texas, United States**

*Sponsored by*  
SPIE

*Cosponsored by*  
4D Technology (United States) • Andor Technology, Ltd. (United Kingdom) • Astronomical Consultants & Equipment, Inc. (United States) • Giant Magellan Telescope (Chile) • GPixel, Inc. (China) • Harris Corporation (United States) • Materion Corporation (United States) • Optimax Systems, Inc. (United States) • Princeton Infrared Technologies (United States) • Symétrie (France) • Teledyne Technologies, Inc. (United States) • Thirty Meter Telescope (United States)

*Cooperating Organizations*  
European Space Organisation • National Radio Astronomy Observatory (United States) • Science & Technology Facilities Council (United Kingdom) • Canadian Astronomical Society (Canada) • Canadian Space Association ASC (Canada) • Royal Astronomical Society (United Kingdom) • Association of Universities for Research in Astronomy (United States) • American Astronomical Society (United States) • Australian Astronomical Observatory (Australia) • European Astronomical Society (Switzerland)

*Published by*  
SPIE

**Volume 10708**  
**Part One of Two Parts**

Proceedings of SPIE 0277-786X, V. 10708

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

The papers in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. Additional papers and presentation recordings may be available online in the SPIE Digital Library at [SPIDigitalLibrary.org](http://SPIDigitalLibrary.org).

The papers reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from these proceedings:

Author(s), "Title of Paper," in *Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy IX*, edited by Jonas Zmuidzinas, Jian-Rong Gao, Proceedings of SPIE Vol. 10708 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510619692

ISBN: 9781510619708 (electronic)

Published by

**SPIE**

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time) Fax +1 360 647 1445

[SPIE.org](http://SPIE.org)

Copyright © 2018, Society of Photo-Optical Instrumentation Engineers.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at [copyright.com](http://copyright.com). Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/18/\$18.00.

Printed in the United States of America

Publication of record for individual papers is online in the SPIE Digital Library.

**SPIE. DIGITAL LIBRARY**

[SPIDigitalLibrary.org](http://SPIDigitalLibrary.org)

---

**Paper Numbering:** *Proceedings of SPIE* follow an e-First publication model. A unique citation identifier (CID) number is assigned to each article at the time of publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online and print versions of the publication. SPIE uses a seven-digit CID article numbering system structured as follows:

- The first five digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc. The CID Number appears on each page of the manuscript.

# Contents

ix *Authors*  
xvii *Conference Committee*

## Part One

### CMB INSTRUMENTS I

---

- 10708 05 **BFORE: a CMB balloon payload to measure reionization, neutrino mass, and cosmic inflation** [10708-4]
- 10708 06 **The primordial inflation polarization explorer (PIPER): current status and performance of the first flight** [10708-5]
- 10708 07 **BICEP Array: a multi-frequency degree-scale CMB polarimeter** [10708-49]

### OPTICS I

---

- 10708 0D **Development of large-diameter flat mesh-lenses for millimetre wave instrumentation** [10708-11]
- 10708 0E **Design and development of a polarization modulator unit based on a continuous rotating half-wave plate for LiteBIRD** [10708-12]
- 10708 0F **Aerogel scattering filters for cosmic microwave background observations** [10708-13]
- 10708 0G **Metamaterial-based Toraldo pupils for super-resolution at millimetre wavelengths** [10708-14]

### SUBMM/FIR CAMERAS

---

- 10708 0J **Optical design of the ToITeC millimeter-wave camera** [10708-17]
- 10708 0K **The SAFARI detector system** [10708-18]
- 10708 0L **Preflight characterization of the BLAST-TNG receiver and detector arrays** [10708-19]
- 10708 0M **MUSCAT: the Mexico-UK Sub-Millimetre Camera for AsTronomy** [10708-20]

---

#### COHERENT DETECTION I

---

- 10708 0Y **Evaluation of controllers for tuning digitizers in the ALMA interferometer** [10708-32]
- 10708 0Z **4×2 HEB receiver at 4.7 THz for GUSTO** [10708-33]
- 10708 12 **Technical achievements of the ALMA future receiver development program at the National Astronomical Observatory of Japan** [10708-36]

---

#### COHERENT DETECTION II

---

- 10708 13 **A proposal of a photonic local system for the extended Atacama large millimeter/submillimeter array and advanced radio interferometers** [10708-37]
- 10708 14 **Planar superconductor-insulator-superconductor mixer array receivers for wide field of view astronomical observation** [10708-38]
- 10708 15 **GLT receiver commissioning at JCMT and future JCMT instrumentation** [10708-39]
- 10708 16 **Electronics instrumentation for the Greenland telescope** [10708-40]

---

#### MULTIPLEXED READOUT

---

- 10708 1D **Digital frequency multiplexing with sub-Kelvin SQUIDs** [10708-47]

---

#### CMB INSTRUMENTS II

---

- 10708 1G **The STRIP instrument of the Large Scale Polarization Explorer: microwave eyes to map the Galactic polarized foregrounds** [10708-50]

---

#### SUBMM/FIR SPECTROMETERS II

---

- 10708 1O **The design and characterization of a 300 channel, optimized full-band millimeter filterbank for science with SuperSpec** [10708-58]

---

#### NEW DEVELOPMENTS

---

- 10708 1U **Prime-Cam: a first-light instrument for the CCAT-prime telescope** [10708-64]

- 10708 1V **Development of a robust, efficient process to produce scalable, superconducting kilopixel far-IR detector arrays** [10708-65]
- 10708 1W **Ultra-low-noise transition edge sensors for far infrared wavelengths: optical design, measurement and stray light control** [10708-66]
- 10708 1X **Eliminating stray radiation inside large area imaging arrays** [10708-67]

---

**POSTER SESSION: CMB DETECTORS I**

- 10708 1Y **Design and characterization of the Cosmology Large Angular Scale Surveyor (CLASS) 93 GHz focal plane** [10708-68]

---

**POSTER SESSION: CMB INSTRUMENTS I**

- 10708 27 **Cooldown strategies and transient thermal simulations for the Simons Observatory** [10708-77]
- 10708 28 **The Cosmology Large Angular Scale Surveyor receiver design** [10708-78]
- 10708 29 **Simons Observatory large aperture telescope receiver design overview** [10708-79]
- 10708 2A **Design and characterization of a ground-based absolute polarization calibrator for use with polarization sensitive CMB experiments** [10708-80]
- 10708 2B **QUBIC: the Q and U bolometric interferometer for cosmology** [10708-81]
- 10708 2D **BICEP array cryostat and mount design** [10708-83]
- 10708 2E **High-precision scanning water vapor radiometers for cosmic microwave background site characterization and comparison** [10708-84]
- 10708 2F **Preliminary scanning strategy analysis for the LSPE-STRIP instrument** [10708-85]

---

**POSTER SESSION: OPTICS I**

- 10708 2G **Design and performance of wide-band corrugated walls for the BICEP Array detector modules at 30/40 GHz** [10708-86]
- 10708 2H **Next generation sub-millimetre wave focal plane array coupling concepts: an ESA TRP project to develop multichroic focal plane pixels for future CMB polarisation experiments** [10708-87]
- 10708 2I **Simulations and performance of the QUBIC optical beam combiner** [10708-88]

10708 2K **Ultra-thin large-aperture vacuum windows for millimeter wavelengths receivers** [10708-90]

## Part Two

10708 2M **Variable-delay polarization modulators for the CLASS telescopes** [10708-92]

10708 2N **2017 upgrade and performance of BICEP3: a 95GHz refracting telescope for degree-scale CMB polarization** [10708-93]

10708 2P **SiAl alloy feedhorn arrays: material properties, feedhorn design, and astrophysical applications** [10708-146]

---

### POSTER SESSION: COHERENT DETECTION

---

10708 2R **Analysis techniques for complex field radiation pattern measurements** [10708-96]

10708 2S **A VLBI receiving system for the South Pole Telescope** [10708-97]

10708 2U **Low-power CMOS digital electronics for radio, mm-wave and sub-mm astrophysics** [10708-99]

10708 2V **The new heterodyne receiver system for the ASTE radio telescope: three-cartridge cryostat with two cartridge-type superconducting receivers** [10708-100]

10708 2X **Development of a low-power cryogenic MMIC HEMT amplifier for heterodyne array receiver application** [10708-102]

10708 32 **Q-band single pixel receiver development for the ngVLA and NRC** [10708-36]

10708 33 **Performance of pre-production band 1 receiver for the Atacama Large Millimeter/submillimeter Array (ALMA)** [10708-46]

10708 34 **A digital beamformer for the advanced focal array demonstrator (AFAD)** [10708-58]

10708 35 **The first-light receivers for the Greenland Telescope** [10708-149]

10708 36 **Progress in the construction and testing of the Tianlai radio interferometers** [10708-150]

10708 37 **Overview of the East Asia ALMA development program** [10708-152]

---

### POSTER SESSION: FIR CAMERAS

---

10708 38 **Latest results and prospects of the ArTeMIS camera on APEX** [10708-107]

10708 39 **Upgrading SCUBA-2 with a newly designed thermal filter stack** [10708-108]

---

**POSTER SESSION: FIR DETECTORS**

---

10708 3C **Revisiting the optimization of the SCUBA-2 TES arrays for POL-2 and FTS-2 operations** [10708-111]

---

**POSTER SESSION: FIR SPECTROSCOPY**

---

10708 3F **TIME millimeter wave grating spectrometer** [10708-114]

10708 3G **The optical design of a far Infrared spectrometer for SPICA: grating modules evaluation**  
[10708-115]

---

**POSTER SESSION: OPTICS II**

---

10708 3H **Use of evolutionary computing algorithms in the design of millimetre-wave metamaterial devices** [10708-116]

10708 3I **Fabrication and characterization of a NIR-FIR dichroic for the infrared interferometer BETTII**  
[10708-117]

10708 3M **Characterizing and reducing the POL-2 instrumental polarization** [10708-121]

---

**POSTER SESSION: CMB DETECTORS II**

---

10708 3O **Fabrication and characterization of cooled silicon bolometers for mm wave detection**  
[10708-123]

---

**POSTER SESSION: CMB INSTRUMENTS II**

---

10708 3U **Systematic error cancellation for the PIXIE four-port interferometric polarimeter** [10708-129]

10708 3V **Thermal architecture for the QUBIC cryogenic receiver** [10708-130]

10708 3W **Design and characterization of the POLARBEAR-2b and POLARBEAR-2c cosmic microwave background cryogenic receivers** [10708-131]

10708 3X **Simons Observatory large aperture receiver simulation overview** [10708-132]

- 10708 3Z **Studies of systematic uncertainties for Simons Observatory: detector array effects** [10708-134]
- 10708 40 **Development of calibration strategies for the Simons Observatory** [10708-135]
- 10708 41 **Designs for next generation CMB survey strategies from Chile** [10708-136]
- 10708 42 **BoloCalc: a sensitivity calculator for the design of Simons Observatory** [10708-137]
- 10708 43 **Broadband anti-reflective coatings for cosmic microwave background experiments**  
[10708-138]

---

**POSTER SESSION: MULTIPLEXING**

- 10708 44 **The FDM readout for the LSPE/SWIPE TES bolometers** [10708-139]
- 10708 45 **Performance of NbSi transition-edge sensors readout with a 128 MUX factor for the QUBIC experiment** [10708-140]
- 10708 46 **Investigation of magnetic shielding for superconducting readout** [10708-141]

---

**POSTER SESSION: OPTICS III**

- 10708 47 **Prototype design and evaluation of the nine-layer achromatic half-wave plate for the LiteBIRD low frequency telescope** [10708-142]
- 10708 49 **Cross-polarization systematics due to Mizuguchi-Dragone condition breaking by a continuously rotating half-wave plate at prime focus in the Huan Tran telescope** [10708-144]
- 10708 4A **Multi-octave anti-reflection coating for polypropylene-based quasi-optical devices**  
[10708-145]
- 10708 4B **Feedhorn development and scalability for Simons Observatory and beyond** [10708-147]



Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy IX, Volume 10708; doi:10.1117/12.2312867. Show/hide abstract. The publisher has not yet granted permission to display this abstract. Astro2010 Technology White Paper: Coherent Detector Arrays for Millimeter and Submillimeter Astronomy Paul F. Goldsmith (Paul.F.Goldsmith@jpl.nasa.gov 818-393-0518) Jet Propulsion Laboratory, California Institute of Technology John Carpenter (CIT), Neal Erickson (UMass), Rick Fisher (NRAO), John Ford (NRAO), Todd Gaier (JPL), Chris Groppi (UAz), Andy.Â We discuss a program for the next decade to develop such technology for ground-based and spacebased millimeter and submillimeter astronomy. Appropriate technologies exist, but significant effort is required to make the transition from simply replicating individual pixels to approaching focal plane array design in an integrated fashion from feeds to spectrometers for spectral analysis.