# Cryocoolers 14 Preface

The objective of *Cryocoolers 14* is to archive the latest developments and performance measurements in the field of cryocoolers by drawing upon the work of leading international experts. In particular, this book is based on their contributions at the 14th International Cryocooler Conference that was held in Annapolis, Maryland, on June 14-16, 2006. The program of this conference consisted of 110 papers; of these, 82 are published here. Although this is the fourteenth meeting of the conference, which has met every two years since 1980, the authors' works have only been made available to the public in hardcover book form since 1994.

Starting this year, the series of Cryocoolers X books is being published in-house by ICC Press using all-electronic manuscripts and digital printing. This has allowed us to also include a CD of the book's contents, in color, within the back cover of each book. Also, consistent with the trend toward instant electronic access to important technical works, color PDFs of each contribution in the book will be available over the internet from the University of Wisconsin web site: http://digital.library.wisc.edu/1711.dl/ICC14 and from our ICC web site http://www.cryocooler.org. This book thus represents a major step forward in the ICC's commitment to archiving and disseminating important technical developments in the field of cryocoolers.

Because the subject content is designed for users of cryocoolers as much as for developers of cryocoolers, extra effort has been made to provide a thorough Subject Index that covers the referenced cryocoolers by type and manufacturer's name, as well as by the scientific or engineering subject matter. Extensive referencing of test and measurement data, and application and integration experience, is included under specific index entries. Contributing organizations are also listed in the Subject Index to assist in finding the work of a known institution, laboratory, or manufacturer. To aide those attempting to locate a particular contributor's work, a separate Author Index is provided, listing all authors and coauthors.

Prior to 1994, proceedings of the International Cryocooler Conference were published as informal reports by the particular government organization sponsoring the conference — typically a different organization for each conference. A listing of previous conference proceedings is presented in the Proceedings Index, at the rear of this book. Most of the previous proceedings were printed in limited quantity and are out of print at this time.

The content of *Cryocoolers 14* is organized into 18 chapters, starting first with a chapter on government cryocooler development programs focused on U.S. civilian and defense space applications. The next several chapters address cryocooler technology developments organized by type of cooler. These start with a chapter on hybrid cryocoolers to provide cooling in the 4-18 K temperature range for large space observatories. Following this chapter are several chapters covering regenerative coolers, including Stirling cryocoolers, pulse tube cryocoolers, Gifford-McMahon cryocoolers, thermoacoustic refrigerators, and associated regenerator research. Although the distinction is becoming blurred with time, separate chapters focus on space cryocoolers versus commercial or industrial cryocoolers. This reflects the difference between one-of-a-kind custom-manufactured cryocoolers for spacecraft applications, as opposed to low-cost mass-producible designs directed toward commercial and industrial applications.

Following the chapters on regenerative cryocooler technologies, three chapters cover recuperative cryocoolers including Joule-Thomson and sorption cryocoolers and their associated

recuperators. The technology-specific chapters end with a chapter on unique sub-Kelvin, magnetic, and optical refrigerators.

The last three chapters of the book deal with cryocooler integration technologies and experience to date in a number of representative space and commercial applications. The articles in these last three chapters contain particularly useful information for the potential user of cryocoolers as well as for the developer.

In reviewing the contributions contained in *Cryocoolers 14*, we note a continuation in movement toward pulse tube cryocoolers for an even wider variety of long-life, high-reliability cryocooler applications. These range in cooling power from less than a watt to over a kilowatt. Pulse tube coolers can be driven by several competing compressor technologies. One class of pulse tube coolers is referred to as "Stirling type" because they are based on the linear Oxford Stirling-cooler type compressor; these generally provide cooling in the 10 to 100 K temperature range and operate at frequencies from 30 to 60 Hz. A second type of pulse tube cooler is the so-called "Gifford-McMahon type." Pulse tube coolers of this type use a GM-type compressor and lower frequency operation (~1 Hz) to achieve temperatures in the 2 to 10 K temperature range. The third type of pulse tube cooler is driven by a thermoacoustic oscillator, a heat engine that functions well in remote environments without electricity. All three types are described, and in total, nearly half of this proceedings covers new developments in the pulse tube arena.

Complementing the work on low-temperature pulse tube and Gifford-McMahon cryocoolers is continued progress on rare earth regenerator materials. These materials continue to enable more and more efficient cryocoolers in the 2 to 10 K temperature range. Also in the commercial sector, continued interest is being shown in the development of long-life, low-cost cryocoolers for the emerging field for hydrogen liquefaction supporting a new hydrogen-based fuel economy. High temperature superconductor electronics and cellular telephone base-stations continue to serve as commercial markets for higher temperature cryocoolers. For these markets pulse tube and Stirling coolers are complemented by closed-cycle J-T or throttle-cycle refrigerators that take advantage of mixed refrigerant gases to achieve low-cost systems in the 65 to 80 K temperature range.

It is hoped that this book will serve as a valuable source of reference to all those faced with the challenges of taking advantage of the enabling physics of cryogenics temperatures. The expanding availability of low-cost, reliable cryocoolers is making major advances in a number of fields.

*The Editors*