

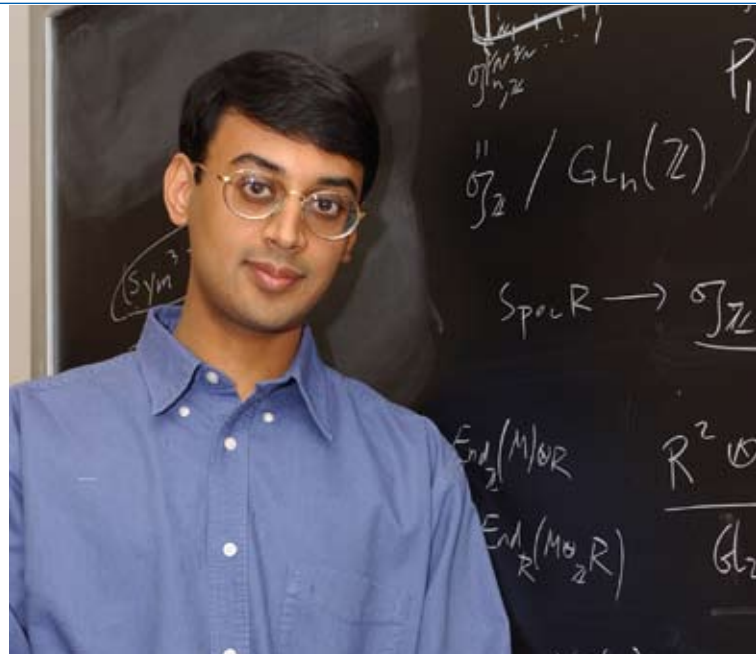
2005 Clay Research Awards

The Clay Mathematics Institute presents the Clay Research Awards annually to recognize contemporary breakthroughs in mathematical research. Awardees receive significant support for their research for one year and the bronze sculpture "Figure-eight Knot Complement vii/CMI" by sculptor Helaman Ferguson. Since 2000, the practice has been to choose one senior and one junior mathematician for the award. Fourteen mathematicians have received the award since its inception in 1999. The first award was presented to Andrew Wiles of Princeton University at the Institute's annual meeting at MIT on May 10, 1999. The most recent awards were presented to Manjul Bhargava and Nils Dencker.

The 2005 Clay Research Awards were given at the Institute's Annual Meeting, held at Oxford University on October 11, 2005 in conjunction with a conference it organized on the publication of a digital edition of the earliest extant manuscript of Euclid's *Elements* (888 AD). At the meeting Andrew Wiles gave a general talk on solving equations. Special thanks to Oxford University, the Mathematical Institute, and the Said Business School for their collaboration and support in hosting the event.

CMI recognizes **Manjul Bhargava** for his discovery of new composition laws for quadratic forms and for his work on the average size of ideal class groups. The field of composition laws had lain dormant for 200 years after the pioneering work of C.F. Gauss. The laws discovered by Bhargava were a complete surprise and led him to another major breakthrough, namely, counting the number of quartic and quintic number fields with a given discriminant. The ideal class group is an object of fundamental importance in number theory. Conjectures of Cohen and Lenstra suggested a proposed answer to this problem. However, there was not a single proven case before Bhargava's work which solved the problem for the 2-part of the class groups of cubic fields. Curiously, in that case, the numerical evidence had led people to doubt the Cohen–Lenstra heuristics.

In his talk on higher composition laws at the awards ceremony in Oxford, Bhargava described how his fascination with Rubik's cube led to his discovery of the new composition laws.



Manjul Bhargava. Denise Applewhite, Office of Communications, Princeton University

As part of Bhargava's research award, the Institute is providing support over a two-year period to the Ramanujan Mathematical Society (RMS). The RMS has established the Clay–Bhargava Fellowship to further the research work of talented graduate students. See www.ramanujanmathsociety.org

Manjul Bhargava was a Clay Research Fellow from 2000 through 2005. In addition to mathematics, his interests include Indian classical music. See www.claymath.org/fas/research_fellows/Bhargava

Manjul Bhargava was born in Hamilton, Ontario, but spent most of his early years in Long Island, New York. He received his AB in Mathematics *summa cum laude* from Harvard University in 1996 and his PhD from Princeton University in 2001 under the direction of Andrew Wiles. After brief visiting positions at the Institute for Advanced Study and Harvard University, he joined the faculty of Princeton University in 2003 as a Professor of Mathematics. Bhargava's primary research interests are in number theory, representation theory, and algebraic geometry, Bhargava has received numerous awards and honors, including three Derek Bok Awards for Excellence in Teaching (1993–95), the Hoopes Prize for Excellence in Scholarly Work and Research from Harvard University (1996), the AMS–MAA–SIAM Morgan Prize for Outstanding Undergraduate Research in Mathematics (1997), the MAA Merten M. Hasse Prize for Exposition (2003), a Packard Foundation Fellowship in Science and Engineering (2004), and the AMS Blumenthal Award for the Advancement of Pure Mathematics (2005). Bhargava was also the Clay Mathematics Institute's first Fellow (2000–05). He was named one of Popular Science magazine's "Brilliant 10" in 2002. Bhargava is an accomplished tabla player.

CMI recognizes **Nils Dencker** for his complete resolution of a conjecture made by F. Trèves and L. Nirenberg in 1970. This conjecture posits an essentially geometric necessary and sufficient condition, *Psi*, for a pseudo-differential operator of principal type to be locally solvable, i.e., for the equation $Pu = f$ to have local solutions given a finite number of conditions on f . Dencker's work provides a full mathematical understanding of the surprising discovery by Hans Lewy in 1957 that there exists a linear partial differential operator – a one-term, third-order perturbation of the Cauchy-Riemann operator – which is not locally solvable in this sense. The necessity of condition *Psi* was shown for operators in dimension 2 by R. Moyer in 1978 and in general by L. Hörmander in 1981. The sufficiency of the condition had resisted many previous attacks.

Nils Dencker was born in 1953 in Lund, Sweden. He received his PhD from Lund University in 1981 under the direction of Lars Hörmander. After spending 1981–1983 as a C.L.E. Moore instructor at MIT, he returned to Lund University where he became Director of Studies in the Department of Mathematics from 2001–2003. Dencker received the Gårding prize in 2003 from the Royal Physiographic Society in Lund. He is currently the Vice Chairman of the Swedish Mathematical Society.

Dencker's research interests are in the microlocal analysis of partial differential equations and calculus of pseudo-differential operators. He has studied the propagation of polarization (vector-valued singularities) for systems of partial differential equations, e.g., in double refraction. Dencker has also studied the pseudospectra (spectral instability) of semi-classical partial differential equations and the solvability of partial differential equations.

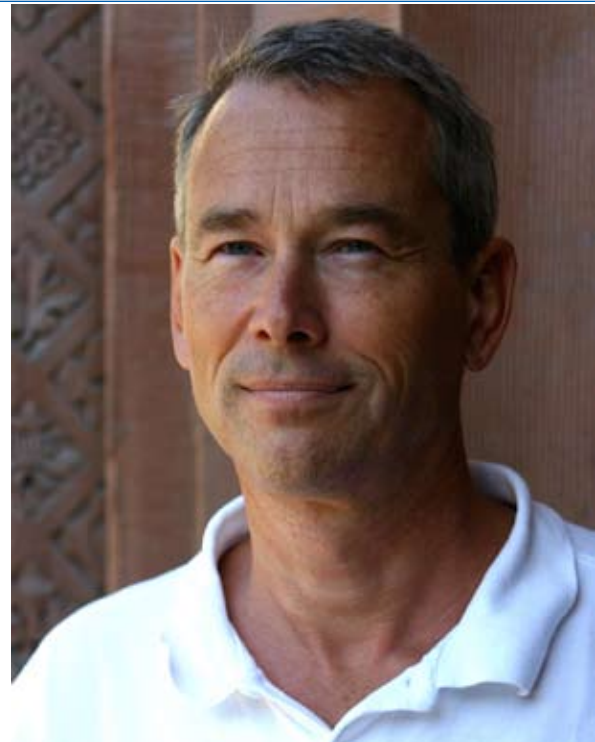
Past Recipients

2004 Ben Green (Bristol University): Arithmetic progressions in the primes.

Gérard Laumon & Bao-Châu Ngô
(Université de Paris-Sud XI, Orsay):
Fundamental lemma in the Langlands
program.

2003 Richard Hamilton (Columbia University):
Ricci flow.

Terence Tao (UCLA): Optimal restriction
theorems in Fourier analysis, Hörn's
conjecture.



Nils Dencker

2002 Oded Schramm (Microsoft Research):
Stochastic Loewner equation.

Manindra Agrawal (Indian Institute of
Technology, Kanpur, India): Primality can
be decided in polynomial time.

2001 Edward Witten (Institute for Advanced Study,
Princeton): Fundamental contributions to
both mathematics and physics.

Stanislav Smirnov (Royal Institute of
Technology, Stockholm): Existence of the
scaling limit of two-dimensional percolation,
verification of Cardy's conjectures.

2000 Alain Connes (Collège de France): For
revolutionizing the field of operator algebras,
for inventing modern non-commutative
geometry.

Laurent Lafforgue (IHES): Work on the
Langlands program.

1999 Andrew Wiles (Princeton University): For
research in number theory.