



ASSESSING THE ECONOMIC IMPACT OF NANOTECHNOLOGY

India Perspective

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INDIAN GOVERNMENT AGENCIES SUPPORTING NANOTECHNOLOGY R&D

Mainly : With specific Nanotechnology Programmes

- Department of Science & Technology (DST)
 - Nano Mission
- Department of Electronics & Information Technology (DeitY)
 - Nanotechnology Initiatives Program
 - Focus on: Nanoelectronics

Others: supporting Nanotechnology projects

- Department of Biotechnology (DBT)
- Defence Research & Development Organization (DRDO)
- Council for Scientific and Industrial Research (CSIR)
- Department of Atomic Research (DAE)
- Department of Space (DOS)
- Indian Council for Agricultural Research (ICAR)
- Indian Council for Medical Research (ICMR)



Promotion of Nano Science and Technology in India

Department of Science & Technology – **Nanomission**-Basic Research Promotion, Infrastructure Development, Nano Applications and Technology Development, Human Resource Development and International Collaborations

Department of Electronics & Information Technology – *Focus on nanoelectronics and technology development, good nanofabrication facilities now at IIT-Bombay, IISc, IITKh, IIT-Delhi; being widely used by university users; Nanometrology Centre at NPL*

Department of Biotechnology, ICMR, ICAR – *projects supported in medical nanobiotechnology (drug delivery, diagnostics, toxicology, etc), agriculture (pathogen detection, pesticide delivery, waste management etc.), aquaculture and other application areas.*

CSIR – *nanotech R&D being carried out by large number of labs on advanced materials drug delivery, sensors and biosensors tissue engineering etc.*

DRDO, DAE and DOS – *large number of labs in consortium mode involved in nanotech R&D relevant for strategic applications.*



NANOTECHNOLOGY INVESTMENTS -INDIA

DST – Nano Mission: Rs. 1000 Cr (US\$ 200 M) over 2001-2011

DeitY -Nanoelectronics: Rs 500 Cr (US\$ 100 M) during 2004-2011

DBT - Rs. 100 Cr. (US\$ 20 M) till 2011

Industry – Rs 1000 Cr (US \$ 250 M) till 2011



DST-NANO MISSION

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- An umbrella programme to promote R&D in Nano Science and Technology
- Built upon the earlier Nano Science and Technology Initiative (NSTI) of DST.
- Objectives of the Nano Mission
 - Basic Research Promotion
 - Infrastructure Development
 - Nano Applications and Technology Development
 - Human Resource Development
 - International Collaborations



DST: NANO MISSION – Main Achievement

- An Institute of Nano Science and Technology, Mohali (INST-Mohali) established.
- Titan Microscope established as a national facility at JNCASR, Bangalore.
- State-of-the art facilities set up in the country and access to such facilities abroad.
- Support to Bureau of Indian Standards and National Physical Laboratory for development of Standards.
- National Task Force constituted to lay down a roadmap for Regulatory Framework for Nano Technology in India.
- 12 Units on Nano Science and 8 Centres for Nanotechnology established in existing institutions.
- Centre for Knowledge Management in Nano Technology, ARCI, Hyderabad (CKMNT)



Department of Electronics & Information Technology (DeitY) Program on Nanotechnology Initiatives

Focus: Nanoelectronics. Budget: Rs. 100Cr (US\$ 20m)/year

Approach

- Competence building, Research and Development focused on Nanoelectronics
- Create infrastructure for research and development in nanoelectronics
- Establish Nanoelectronics Centres
- Enable innovation & Commercialization of technologies



DietY Program on Nanotechnology

Major projects and Centres

- Nanoelectronics Centres at IIT Bombay & IISc Bangalore which are now called **Centres of Excellence in Nanoelectronics (CENs)**. Phase I at US\$ 20M. Phase II at US\$ 30M started from 2012.
- Nanometrology lab at NPL Delhi
- Indian Nanoelectronics Users Program (INUP) at IIT Bombay & IISc Bangalore
- Development of MBE cluster tool based epitaxial nano-semiconductor infrastructure and process integration facility at IIT Kharagpur
- Non-Silicon based Technologies for Nanofabrication and Nanoscale Devices at IIT Delhi
- Centre for Nanoelectromechanical Systems(NEMS) and Nanophotonics at IIT Madras



CEN Phase II: Broad Objectives



A High-tech Eco System

To support technology breakthroughs & completely new ideas

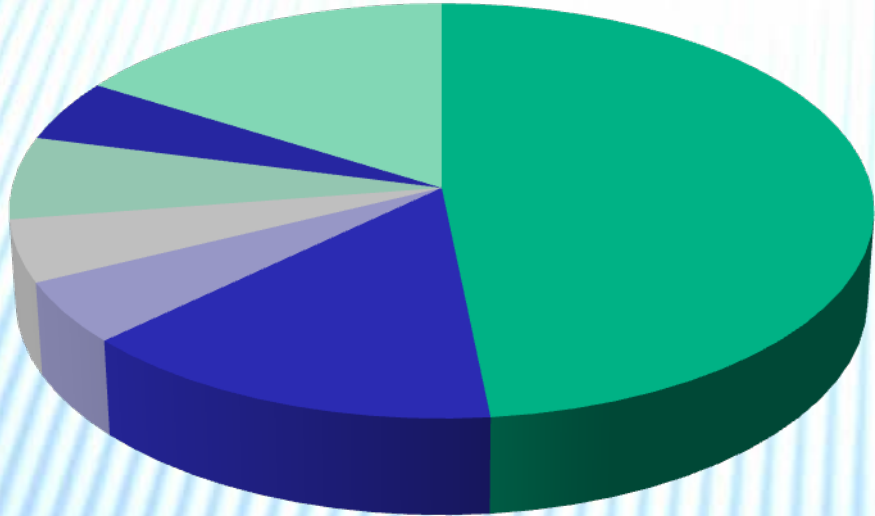
To encourage start-ups and technology entrepreneurs

To support High-tech industries

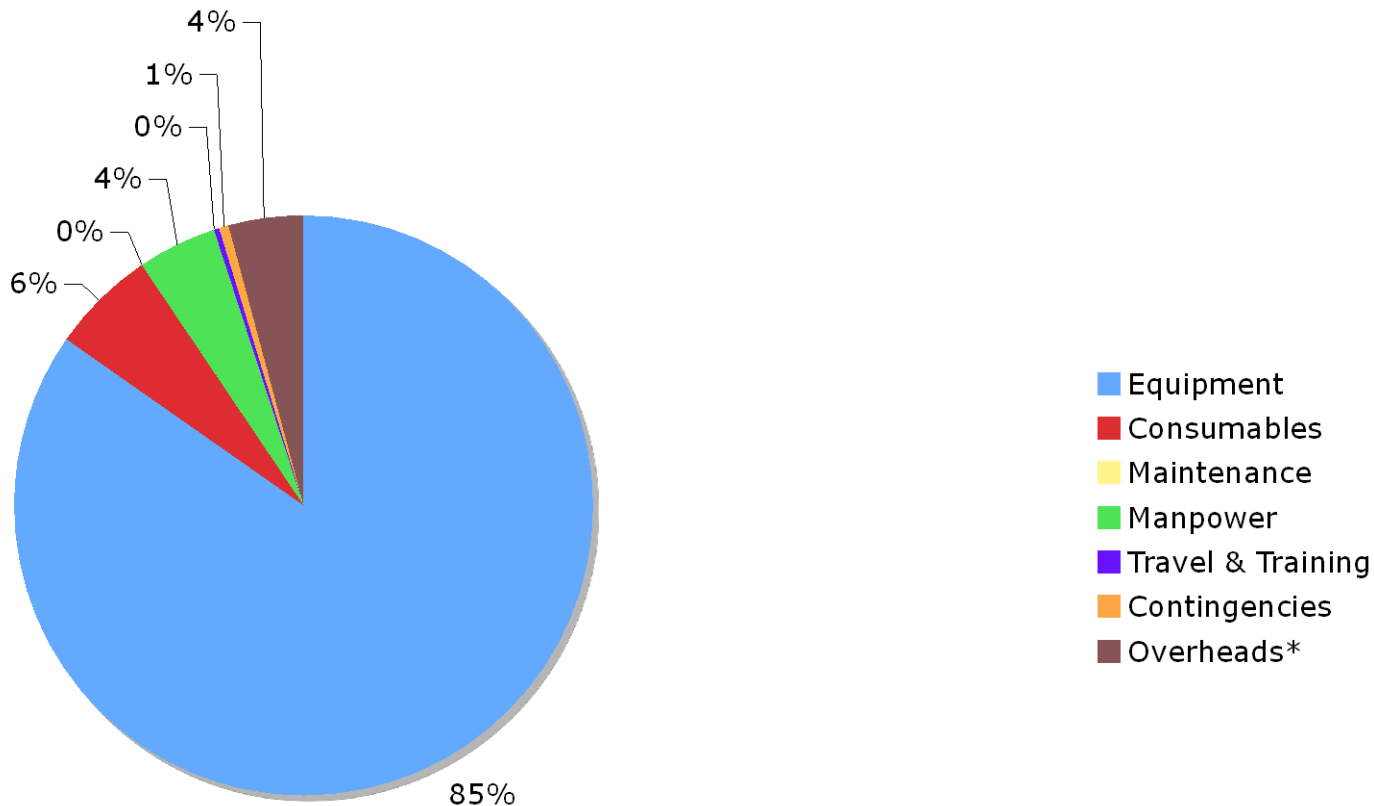


Multi Disciplinary activities in the CENs

Ph.D. Students



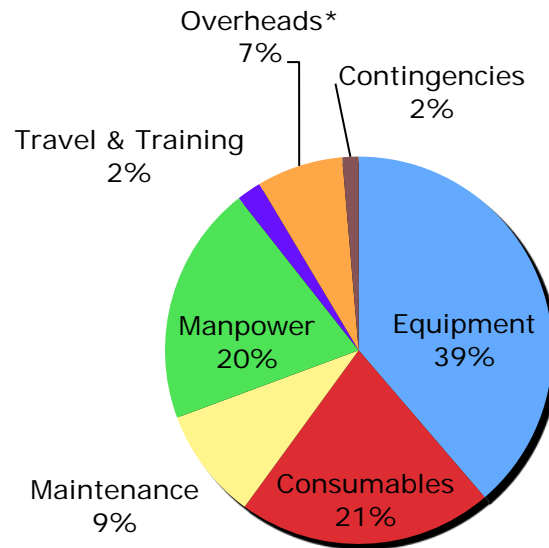
- EE
- Energy Science
- Bio
- Chem & Chem Eng
- CRNTS
- Mech Eng
- Physics



Projects: about 7%
Consumables (6%) + part of manpower
(4%)



CEN Phase II Budget



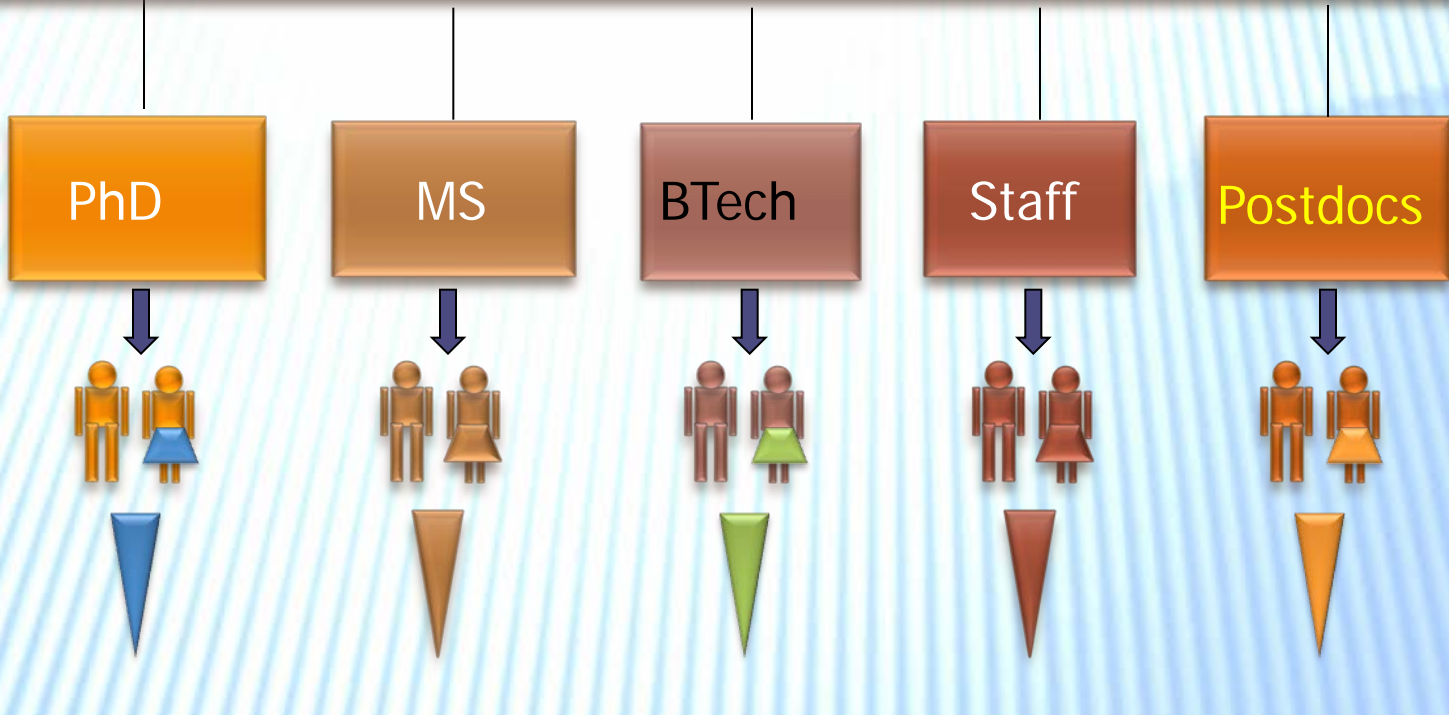
US \$ 30 M

Projects ~ 40%

Consumables (21%) + part of manpower (18%)



Education & HRD in CENs



Graduates per year

~70

86

36

38

9

Total over 5 years

350

430

180

190

45



DIT PROGRAMME ON NANOTECHNOLOGY INITIATIVES

Indian Nanoelectronics Users Program (INUP) at IISc- Bangalore and IIT-Bombay

Scope

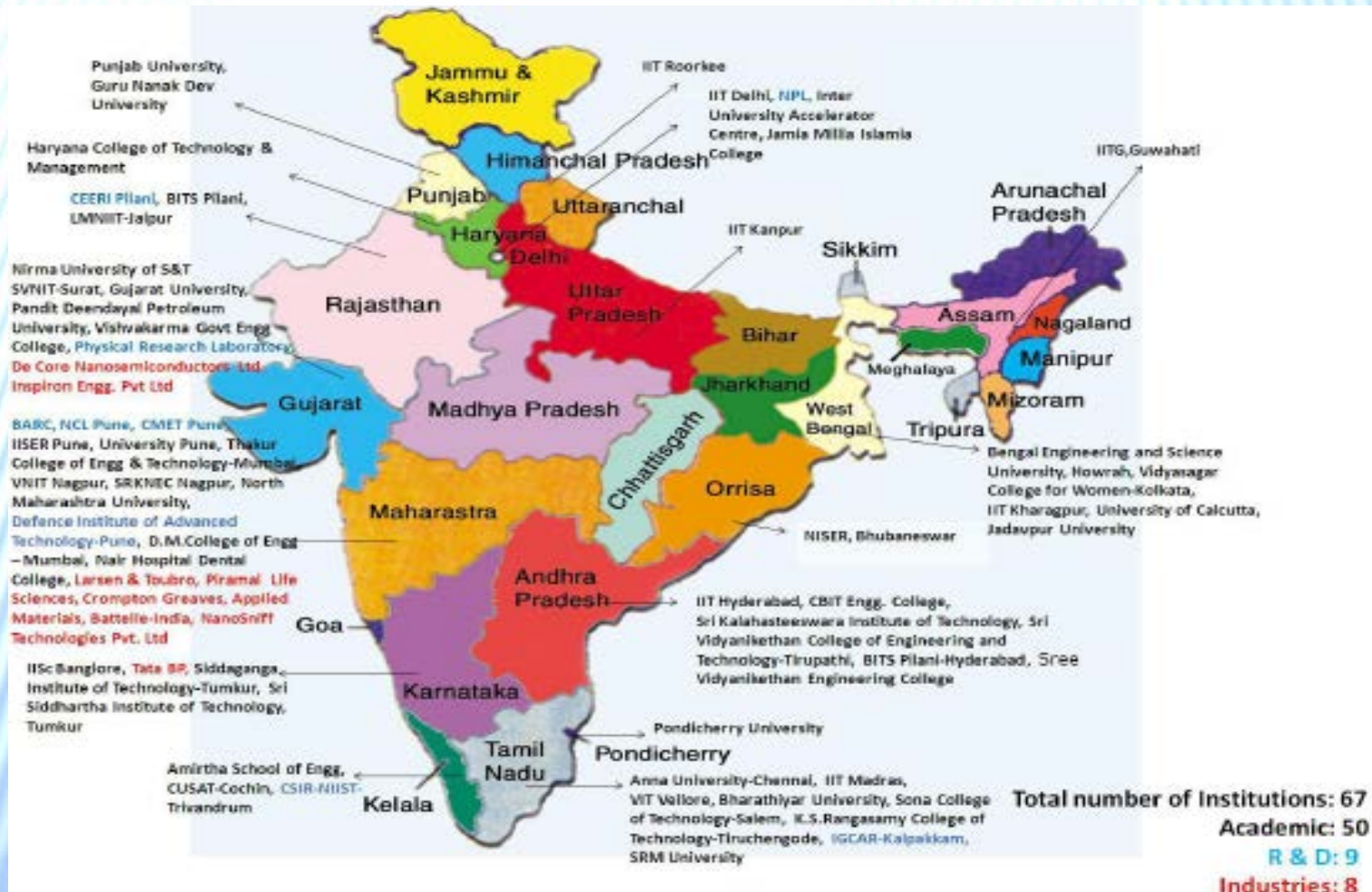
- Impart hands-on training to researchers across institutions in the country in nanoelectronics.
- Assist in the initiation of research in nanoelectronics across the country by enabling execution of the work of external users at these centres.
- Collaborate with research teams at other Indian centres and develop joint programs in nanoelectronics.
- Provide a platform for researchers in nanoelectronics to come together and benefit from complementary expertise.
- Conduct workshops for the wider dissemination of the knowledge in the area of nanoelectronics.

Achievements

- More than 100 projects from about 100 organizations across the country taken up so far. About 1000 researchers from more than 200 organizations trained through INUP.



INDIAN NANO-ELECTRONICS USERS' PROGRAMME: IIT Bombay





Application Development

- Pharmaceuticals
- Information Technology
- Energy
- Biotechnology
- Textiles
- Consumer Products
- Water Purification
- Sports
- Healthcare
- Security
- Environment



SOME NANOTECHNOLOGY DEVELOPMENTS

From Nano Mission Programmes

- IISc, Bangalore - of voltage developing across a single walled carbon nano tube when a liquid flows over it. Granted US Patent. Technology transferred to a US Company.
- IIT-Delhi – very stable silver nanoparticle based antimicrobial finish (with ARCI-Hyderabad) and water-based self-cleaning nanofinish developed; both technologies transferred to a leading specialty textile chemical company in Bangalore; prototype automotive oil filters developed and undergoing field trials with filtration efficiency of upto 99% for 1 μm size standard dust without sacrificing their dust holding capacity.



Prototype of automotive filter using Nanowebs

- IIT-Madras – nanotechnology-based water purification technologies developed and commercialized.



DeitY PROGRAMME ON NANOTECHNOLOGY INITIATIVES

Technology Development

- A bio-sensor platform for cardiac diagnostics suitable for integration towards a complete lab-on-chip development
- Nano-particle based piezo-resistive polymer composite cantilevers for a range of applications focusing on the detection of explosive molecules such as TNT/RDX
- Technology for cardiac markers such as myoglobin using nano-mechanical cantilevers



DeitY PROGRAMME ON NANOTECHNOLOGY INITIATIVES

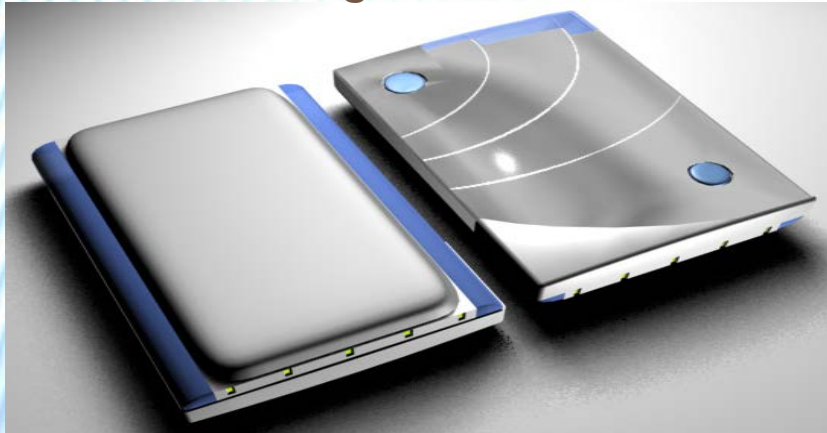
Technology Development

- Nanobiosensors for blood glucose, blood hemoglobin.
- Multi functional magnetic nanoparticulates based biosensor for the detection of cancer
- gas sensor platform for automotive exhaust and environmental pollution monitoring applications
- Piezo resistive based pressure sensors have been fabricated using micromachined silicon membrane.
- Carbon nanotubes based gas sensors



Product Development in the CEN

Silicon Locket for Cardiac Diagnostics



A cantilever based low-cost explosive detector



Explosive detector based on the fluorescence quenching principle



A low-cost portable SPR System

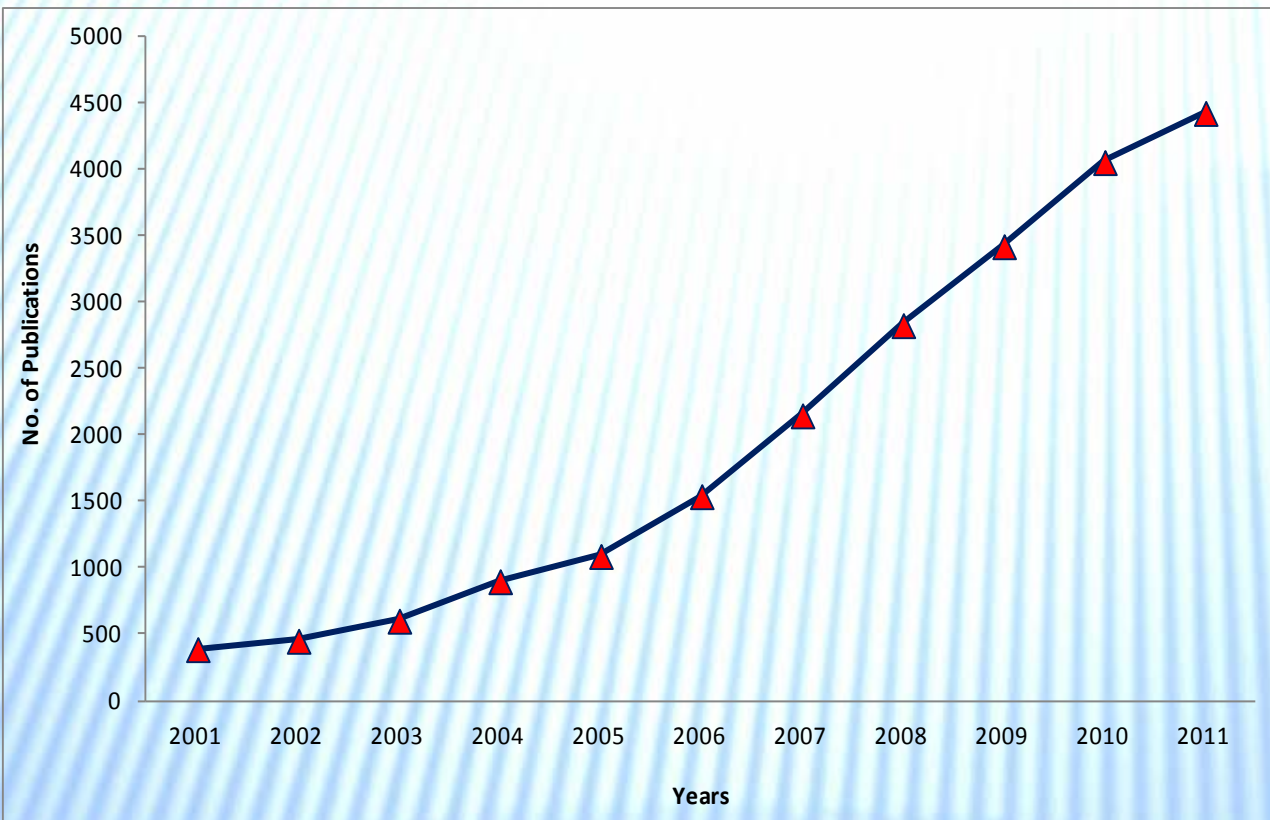


nanosniff

- Angel Funded by Priaas investments, R&D Funding by ICICI SPREAD
- 16 people currently employed in NanoSniff including 5 Ph.D.s
- Three Products: *OmniCant™*, *Explosive Detector*, *iSens*
- OmniCant to be launched in Q1-2012
- Setting up of manufacturing facilities



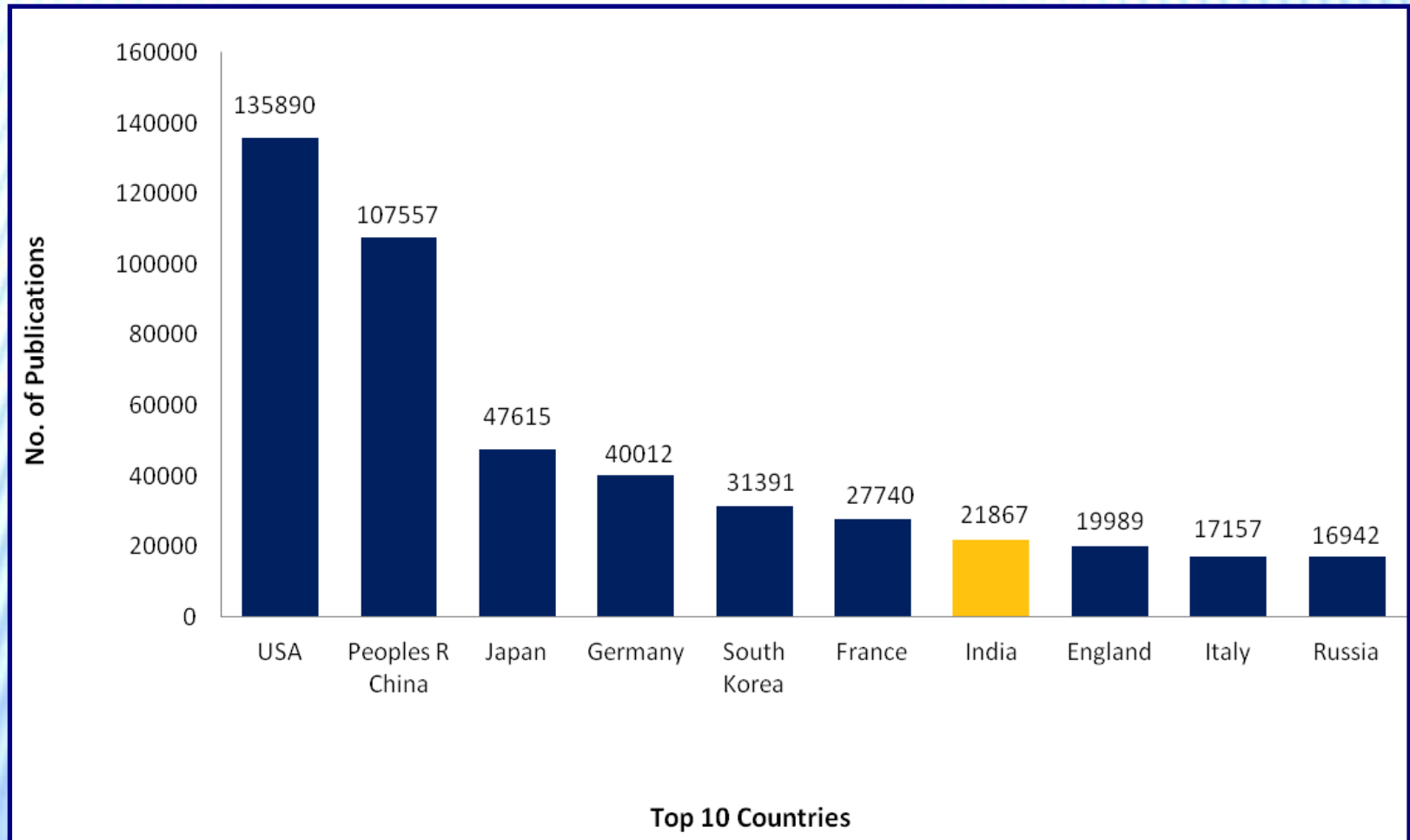
INDIAN SCIENTIFIC PUBLICATIONS IN NANO SCIENCE & TECHNOLOGY IN LAST TEN YEARS (2001-2011)



Year	No. of Publications (2001-2011)
2001	392
2002	455
2003	606
2004	903
2005	1093
2006	1543
2007	2151
2008	2830
2009	3424
2010	4057
2011	4427
Total	21881



TOP 10 COUNTRIES BASED ON LAST TEN YEARS (2001-2011) SCIENTIFIC PUBLICATIONS IN NANO SCIENCE AND TECHNOLOGY

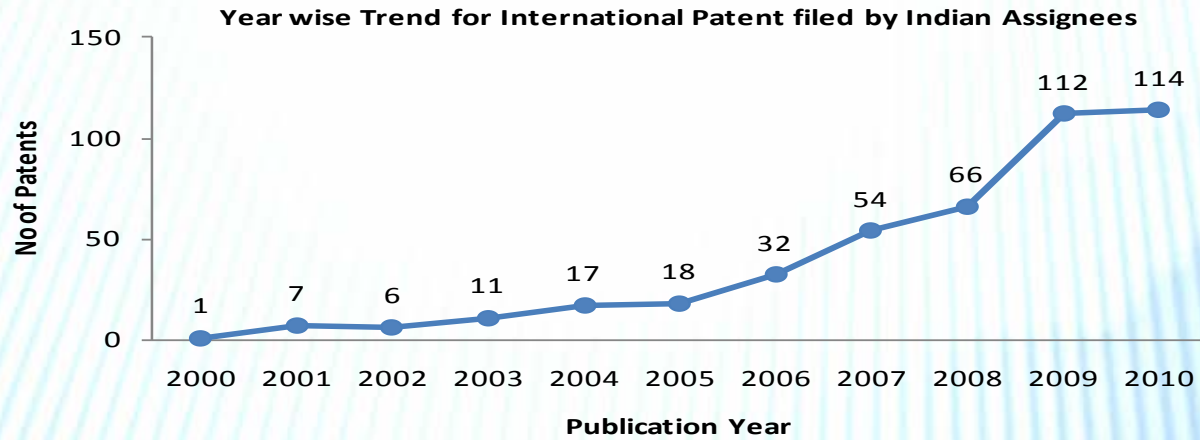




GROWTH RATE OF SCIENTIFIC PUBLICATIONS IN NANO SCIENCE & TECHNOLOGY OF TOP 10 COUNTRIES FOR LAST TEN YEARS (2001-2011)

Top 10 Countries	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Y-o-Y growth (2010-2011)
USA	4553	5971	7973	9667	11820	13131	15048	16465	17477	17365	16601	-4.4%
Peoples R China	1823	2535	3671	5037	6959	8901	11191	13471	15771	18202	20095	10.4%
Japan	2109	2458	3130	3772	4231	4738	5404	5471	5593	5580	5188	-7.0%
Germany	1735	2048	2428	2823	3153	3610	4157	4592	5018	5335	5165	-3.2%
South Korea	577	819	1241	1722	2127	2858	3633	3903	4348	4917	5278	7.3%
France	1064	1356	1618	1844	2282	2539	2796	3385	3560	3713	3618	-2.6%
India	392	455	606	903	1093	1543	2151	2830	3424	4057	4427	9.1%
UK	730	889	997	1246	1465	1785	2137	2533	2681	2848	2696	-5.3%
Italy	509	674	904	1103	1274	1492	1857	2055	2357	2483	2470	-0.5%
Russia	746	881	1077	1283	1288	1424	1803	2014	2140	2297	2019	-12.1%

Source : Vivek Patel & R.Vijaya Chandar, CKMNT/ARCI





THE INDIAN NATIONAL SCENARIO -SWAT

STRENGTHS

- India performing reasonably well in scientific publications
- Active community of ~ 1000 researchers
- Good characterization facilities
- Decent fabrication facilities now in a few institutions
- Indian research – good value for investment

WEAKNESSES

- Progress on technology front slow
- Lab to Commercialization - enabling environment needs considerable strengthening
- Industry reluctant to take risk
- Poor job opportunities in industry for R&D personnel

THREATS

- International competitiveness even in Nano Science will get marginalized if vigorous promotional efforts are not continued
- Opportunities to exploit application potential will get lost if enabling financial, management and regulatory systems not put in place quickly to promote technology development and commercialization.

OPPORTUNITIES

- Sparks of entrepreneurship now visible in a few institutions
- Business community and venture capitalists desirous of investing now
- Development of technologies, products and processes may pick up now if risk-absorbing schemes are put in place quickly



Some Government of India Initiatives for enhancing Manufacturing

- National Manufacturing Competition Council (NMCC): *to provide a continuing forum for policy dialogue to energise and sustain the growth of manufacturing industries in India*
- *Nanoelectronics Innovation Council* Set up recently DeitY
- Special Incentive Package Program (SIPS) *for the Semiconductor and other electronics Industry*
- Rs. 10,000 Cr (US\$ 2 Billion) Electronics Development Fund *proposed to promote innovation, IP, R&D, product development, commercialisation of products, etc, in ESDM, nano-electronics and IT sectors by DeitY*
- Setting up semiconductor fabs



Thank you for your attention!