Electronics and Photonics in China

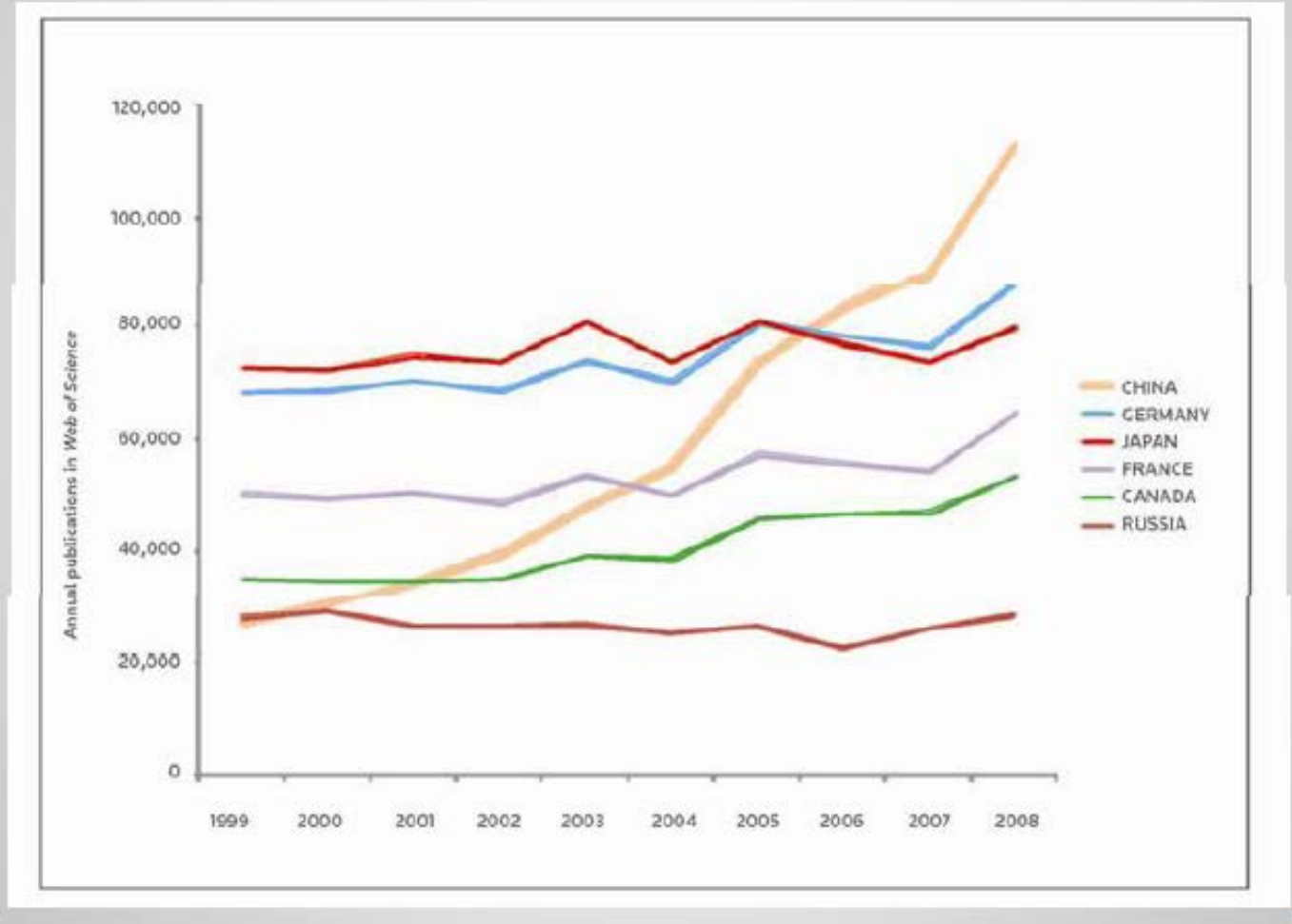
Magnus Breidne

Executive Director - Projects

Outline

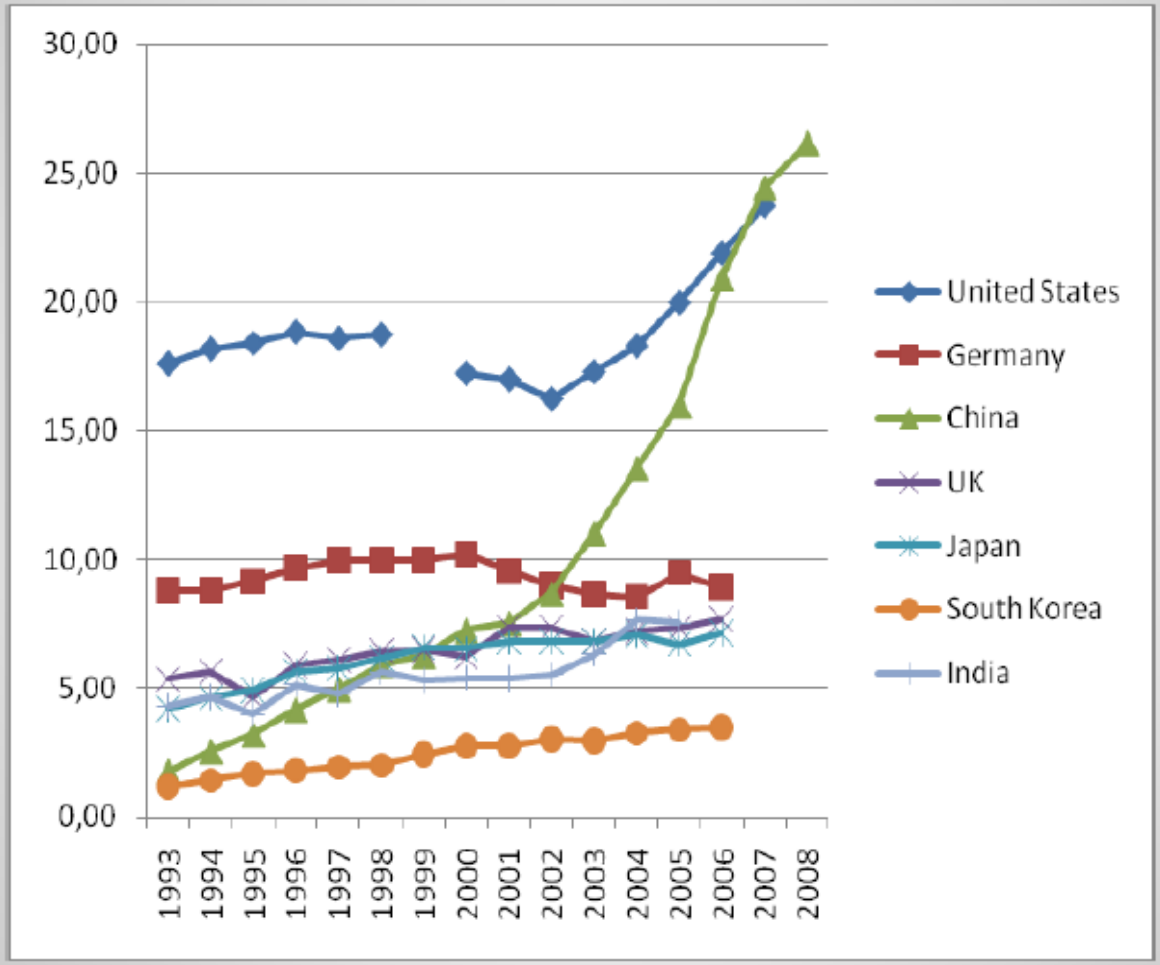
- Why China ?
- Sino - Swedish collaboration today
- Chinese research primary (electronics and photonics)
  - Long and Medium Term Plan for S&T Development
  - MEGA-projects
- Chinese research in silicon photonics

The changing knowledge geography

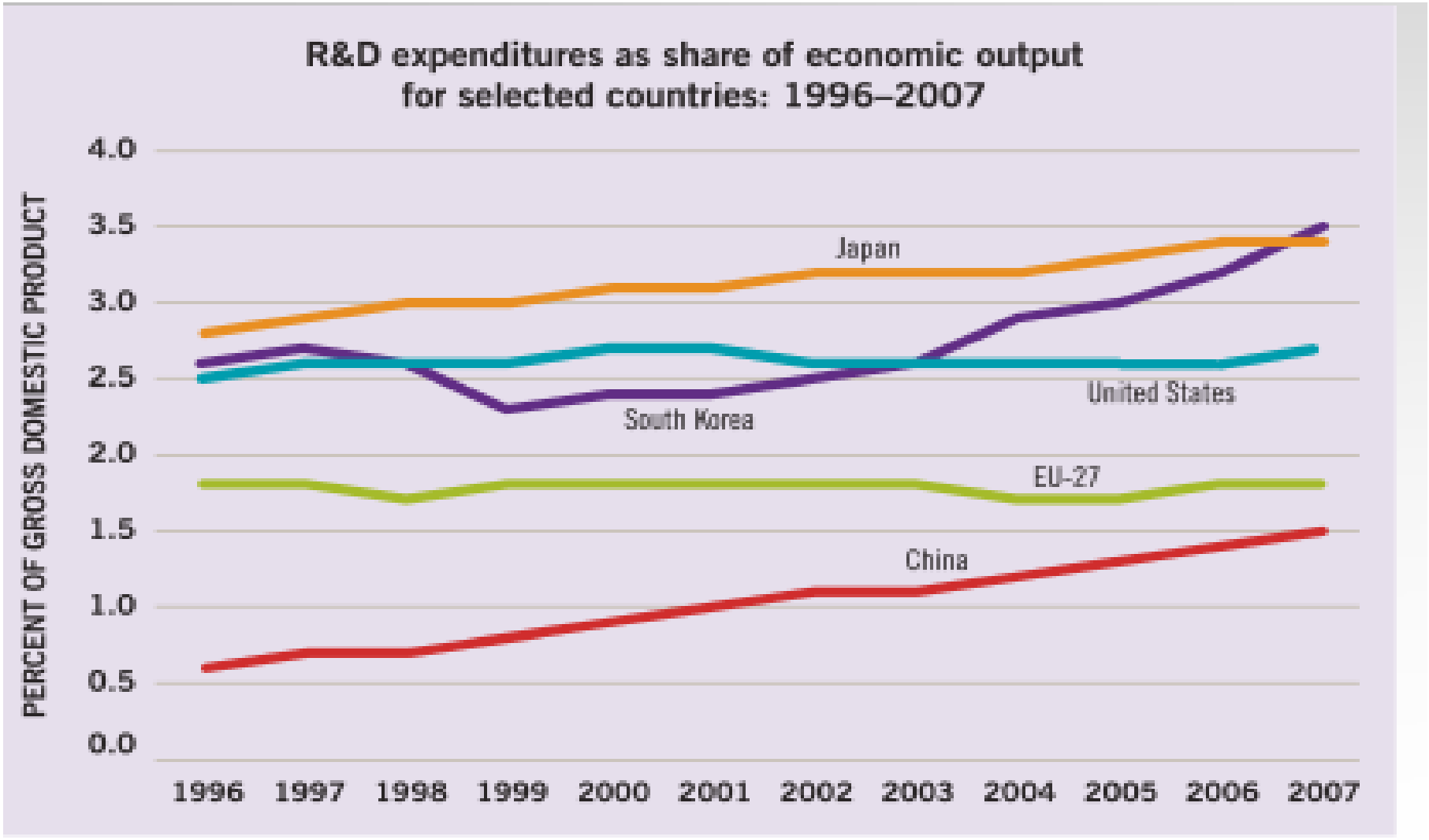


Source: Evidence / Thomson Reuters (2009)

The changing knowledge geography II



Source: National Science Foundation S&E Indicators 2010, China Yearbook of Statistics 2009



EI 2010: Comparison of Country R&D Intensities, Chapter 4.

Copublication China - Sweden

	Antal publikationer / år			Medelcitering		
Område	**Kina**	**K-S***	**Sverige**	**Kina**	**K-S***	**Sverige**
Agronomi	7222	24	1596	1,10	1,51	1,47
Biologi	2758	16	1262	0,75	1,61	1,44
Kemi	20959	132	2410	0,91	1,76	1,23
Fysik	3573	21	738	0,86	1,27	1,17
Geovetenskap	26955	86	1762	0,73	1,04	1,27
Matematik	6171	4	476	1,15	1,28	1,21
Biomedicin	12972	74	4155	0,65	0,89	1,13
Klinisk medicin	10500	90	6764	0,85	1,02	1,40
Ingenjörsvetenskap	13762	43	1347	1,12	1,51	1,21
IKT	9329	40	993	1,03	1,65	1,13
Materialvetenskap	12604	48	890	0,98	1,57	1,15
Hum-Sam	1988	8	1438	0,89	0,97	1,03
Total	**97507**	**437**	**18479**	**0,92**	**1,33**	**1,28**

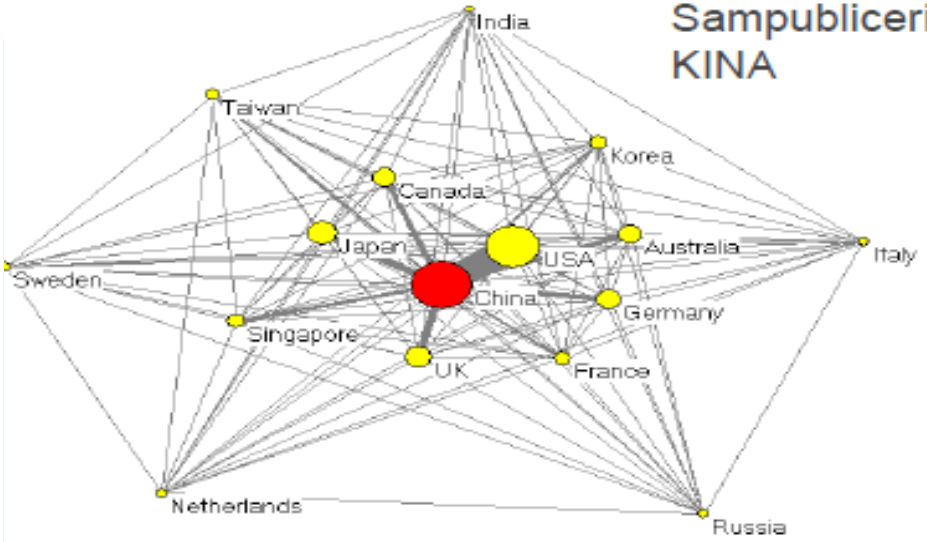
Källa: Vetenskapsrådet, bearbetning av data från Thomson Reuters

Sino – Swedish research cooperation

- Sino-Swedish co-publication has generally a high degree of citation (exception Biomedicine, Geoscience and Clinical medicine)

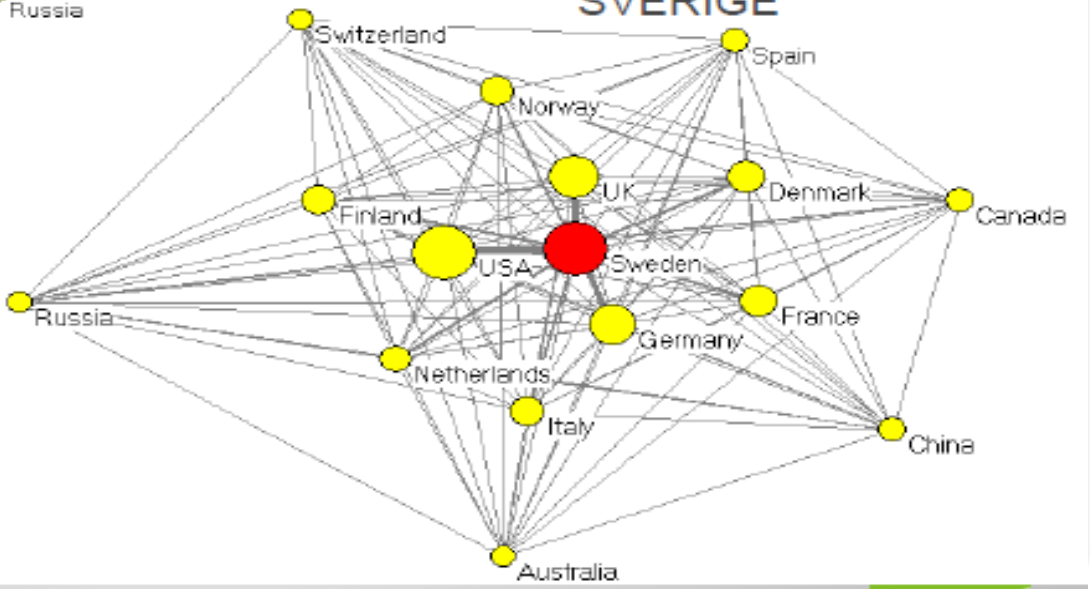
- the cooperation mainly follows the Chinese science activity profile (exception Mathematics and Clinical medicine

Co-publication patterns



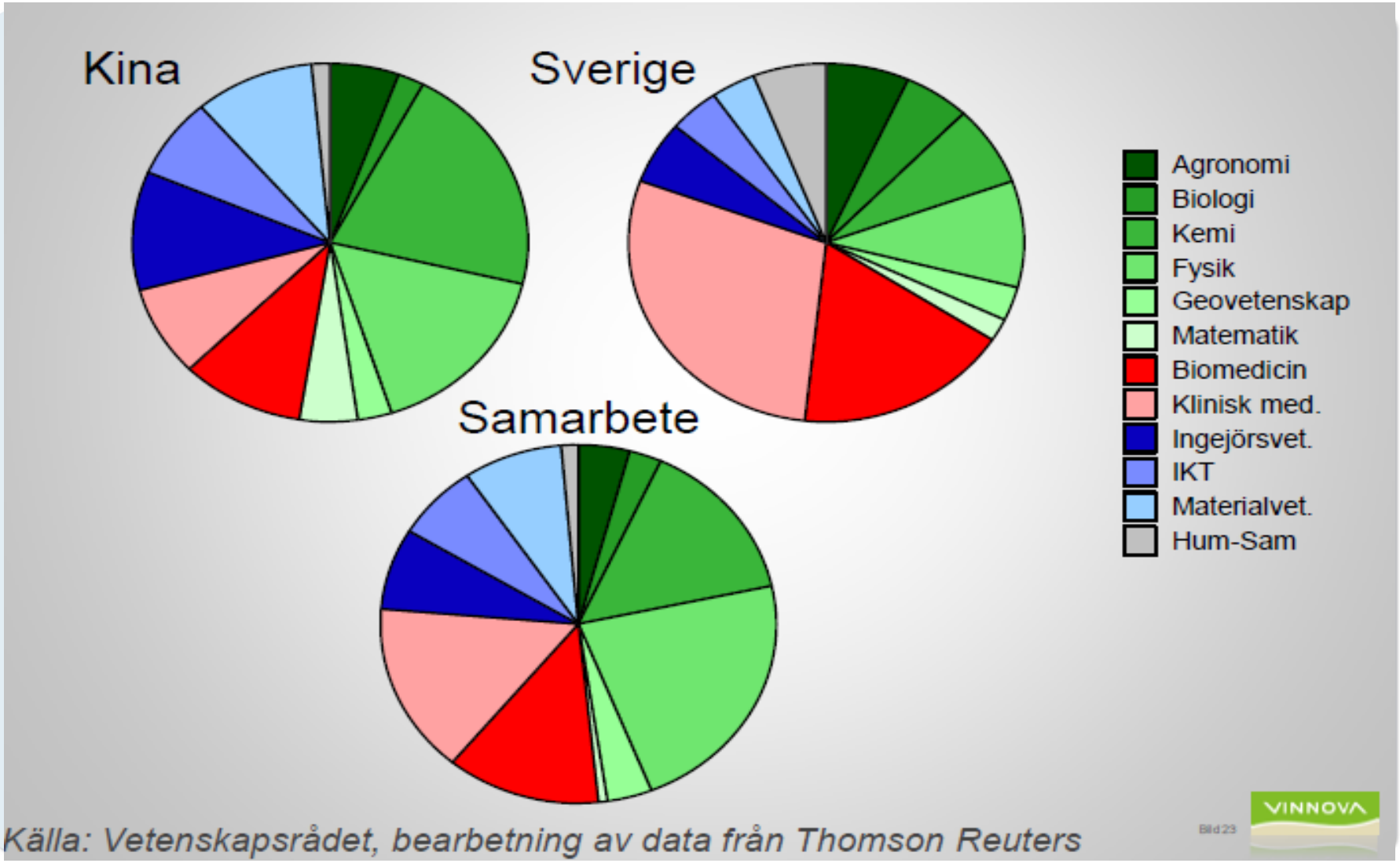
Sampubliceringsmönster
KINA

Sampubliceringsmönster
SVERIGE



Källa: Vetenskapsrådet, bearbetning av data från Thomson Reuters

What ?



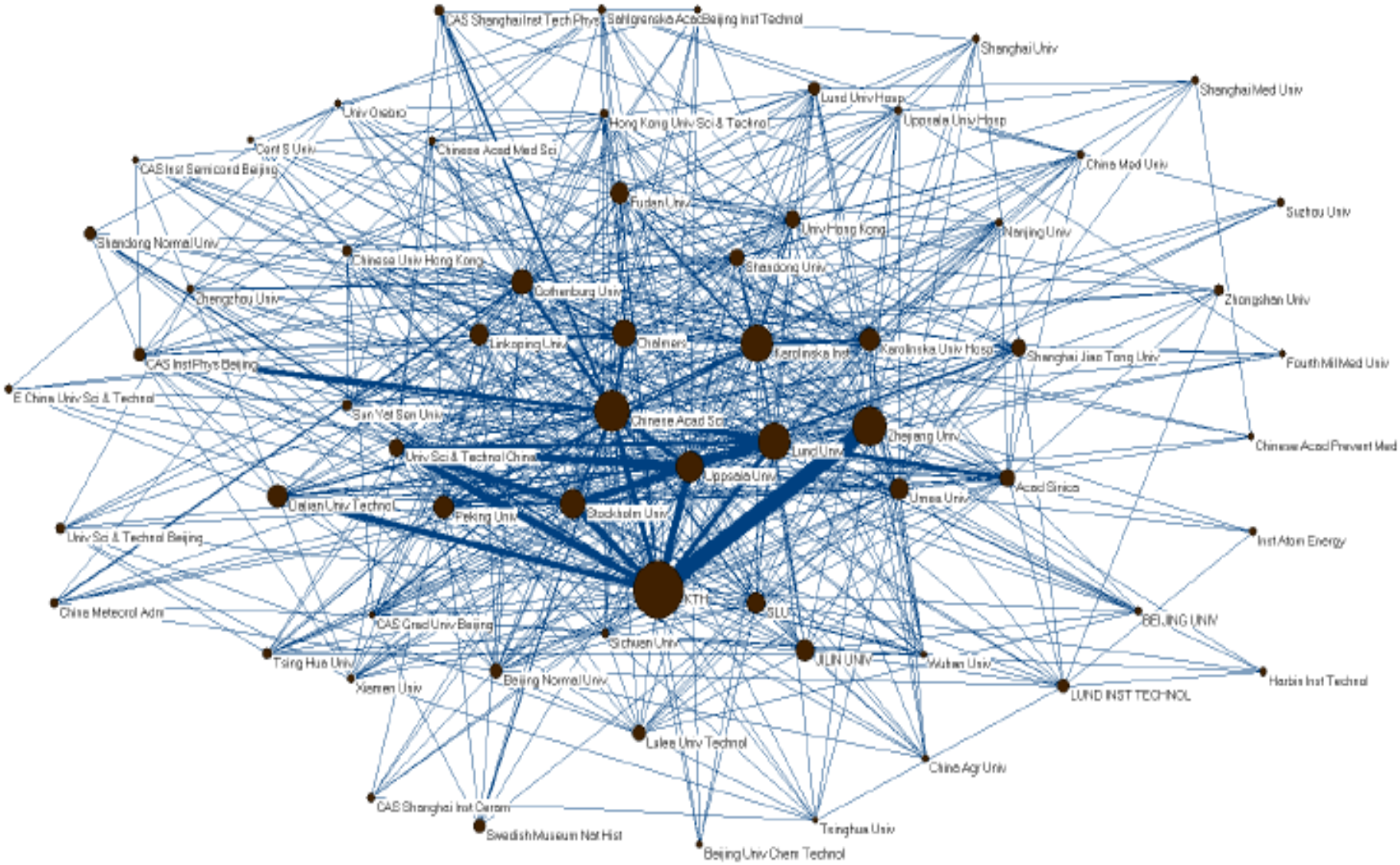
Källa: Vetenskapsrådet, bearbetning av data från Thomson Reuters

Who ?

Åren 2005-2009					
Kina	**Sampubl. per år**	**Medel-citering**	**Sverige**	**Sampubl. per år**	**Medel-citering**
Chinese Acad Sci	72	1,21	Royal Institute of Technol.	133	1,60
Zhejiang Univ	53	1,69	Karolinska Institutet	65	1,02
Dalian Univ Technol	28	2,17	Lund University	52	1,14
Fudan Univ	21	1,26	Uppsala University	45	1,23
Peking Univ	19	0,97	Stockholm University	38	1,76
Shandong Univ	17	0,97	Karolinska Univ. Hospital	33	0,83
Jilin Univ	16	1,10	University of Gothenburg	29	1,07
Shanghai Jiao Tong Univ	15	1,21	Chalmers Univ. of Technol,	22	1,11
Univ Hong Kong	13	1,03	Linköping University	18	0,84

Källa: Vetenskapsrådet, bearbetning av data från Thomson Reuters

Royal Swedish Academy of Engineering Sciences



Outline

- Why China ?
- What is the collaboration situation today ?
- Chinese research primary (electronics and photonics)
- Chinese research in silicon photonics

China's targets for 2020

Key Objectives of China's Medium and Long- Term S&T plan

- R&D intensity to reach 2% of GDP in 2010, and 2.5 % by 2020
- S&T and innovation to contribute to 60% of GDP growth
- Dependence on foreign technology to be reduced to less than 30% (ratio of expenditure on technology import to R&D expenditure, estimated at 56% in 2004)
- To be among the top-5 worldwide in terms of the number of domestic invention patents granted, and the number of international citations of scientific papers, and aiming at breakthroughs in certain fields of technology

Structure of ’Expert group’ reports

- Global situation
- Domestic demands
- Problems
- Key projects (programmes)
- Policy measures

MEGA-projects – China's way to innovation !??

分类

目前进行的项目规划分为13类：

1 核心电子器件、高端通用芯片及基础软件产品专项
2 极大规模集成电路制造装备与成套工艺专项
3 新一代宽带无线移动通信网专项
4 高档数控机床与基础制造装备专项
5 大型油气田及煤层气开发专项
6 大型先进压水堆及高温气冷 堆核电站专项
7 水体污染控制与治理专项
8 转基因生物新品种培育专项
9 重大新药创制专项
10 艾滋病和病毒性肝炎等重大传染病防治专项
11 大型飞机专项
12 高分辨率对地观测系统专项
13 载人航天与探月工程专项

MEGA projects – general characteristics

- Each MEGA project will each have more than RMB 10 bn in government support and will be finished by 2020.
- Estimated that central government, local governments and enterprises together could invest up to RMB 1 trillion in some projects
- In comparison, into ICT during last five years
  - RMB 4 bn of governmental support to “863” plan
  - RMB 1 - 2 bn in governmental support to “973” plan

MEGA projects

- core electronic components
- high-end universal chips and basic software
- very-large-scale integrated circuit manufacturing technologies
- new-generation broadband wireless mobile communications
- high-grade numerically-controlled machine tools
- development of large oil and gas fields and coal-bed gas
- nuclear power stations
- water pollution control and treatment
- cultivation of new strains of genetically modified organisms
- manufacturing of new major drugs
- prevention and treatment of AIDS and other infectious diseases
- large aircraft
- high-resolution earth observation systems
- manned spaceflight
- moon exploration programme

Main goals of IT MEGA projects

- Develop key technologies, and research a number of strategic core products;
  - By 2020, in the fields of high-end general chip, basic software and core electronic devices, China should form high-tech research and innovation system which has international competitive power;
  - The ecosystem of IT innovation and development should be optimized, and there should be a group of international and high-level talents and an improved self-innovation system.

Core electronic devices

Central tasks:

- Core electronic devices oriented towards all types of significant equipment;
- Emphasis on R&D of large-scale general databases, management systems and tools, servers for network applications, middleware for network applications, office software for network applications, and construction of related integration and development software, aiming at the demands of national mega informatization application projects and domestic basic software and integration applications.

High-end general chips and basic software

Central tasks:

- Research and develop processing chips oriented towards high performance computers;
- Emphasis on R&D of IC chips oriented towards telecommunications, multimedia processing and personal media mobile communication terminals;
- Emphasis on R&D of large-scale general databases, management systems and tools, servers for network applications, middleware for network applications, office software for network applications, and construction of related integration and development software, aiming at the demands of national mega informatization application projects and domestic basic software and integration applications.

High-end general chips and basic software

- Safety SoC (system on a chip) chip
- Multi-core CPU for high-performance server
- Safety and applicable computer CPU
- High-performance embedded CPU
- SoC chip for personal mobile information terminal
- Storage control Soc and mobile storage chip
- DTV SoC chip
- High-performance IP core technology
- EDA development tool.

New Generation Wireless Broadband Network

- TD-SCDMA enhanced R&D and industrialization;
- LTE R&D and industrialization;
- IMT-Advanced R&D and industrialization;
- Mobile Network, service application and terminal R&D;
- Broadband wireless access R&D and industrialization;
- Short distance wireless interconnection and wireless sensor network R&D and industrialization;
- Common and key technologies R&D and project management support of wireless mobile communication.

New Generation Wireless Broadband Network

The Ministry of Finance alone is reported to be planning to invest at least 20 billion RMB toward what could be a total project investment exceeding 70 billion RMB (Source: Caijing. Remaining funds expected to come from industry).

In comparison, the government has invested only 5 billion RMB in TD technology over the past 10 years.

VLSI Manufacture Equipment

- Integrated Circuit Equipment
- Key Components and Core Technology
- Complete Sets of Process
- Key Materials
- Prospective Study

Photonics

In the beginning of 2001 the Chinese government designated *Optoelectronics* as one of the top ten emerging industries and begun intensive efforts to promote its development.

- *Beijing: 20 billion yuan (US$1.2 billion) was invested* during the 10th Five-Year Plan
- *Guangdong: Plans to create 10 enterprises with annual sales* of 5 billion yuan (US$600 million) and another 30 enterprises with annual sales of 10 billion yuan (US$120 million).

Photonics cont'd

- *Wuhan: A total of 24 billion yuan (US$2.9 billion) was invested* during the 10th Five-Year Plan to set up an industrial park covering 50 square kilometers, with annual sales of 100 billion yuan (US$120 billion).

- *Changchun: The first-phase investment of 24.9 billion yuan* (US$3 billion) will go toward an industrial park of 30 square kilometers. By the end of the 10th Five-Year Plan, annual sales are expected to total 80 billion yuan (US$9.6 billion).

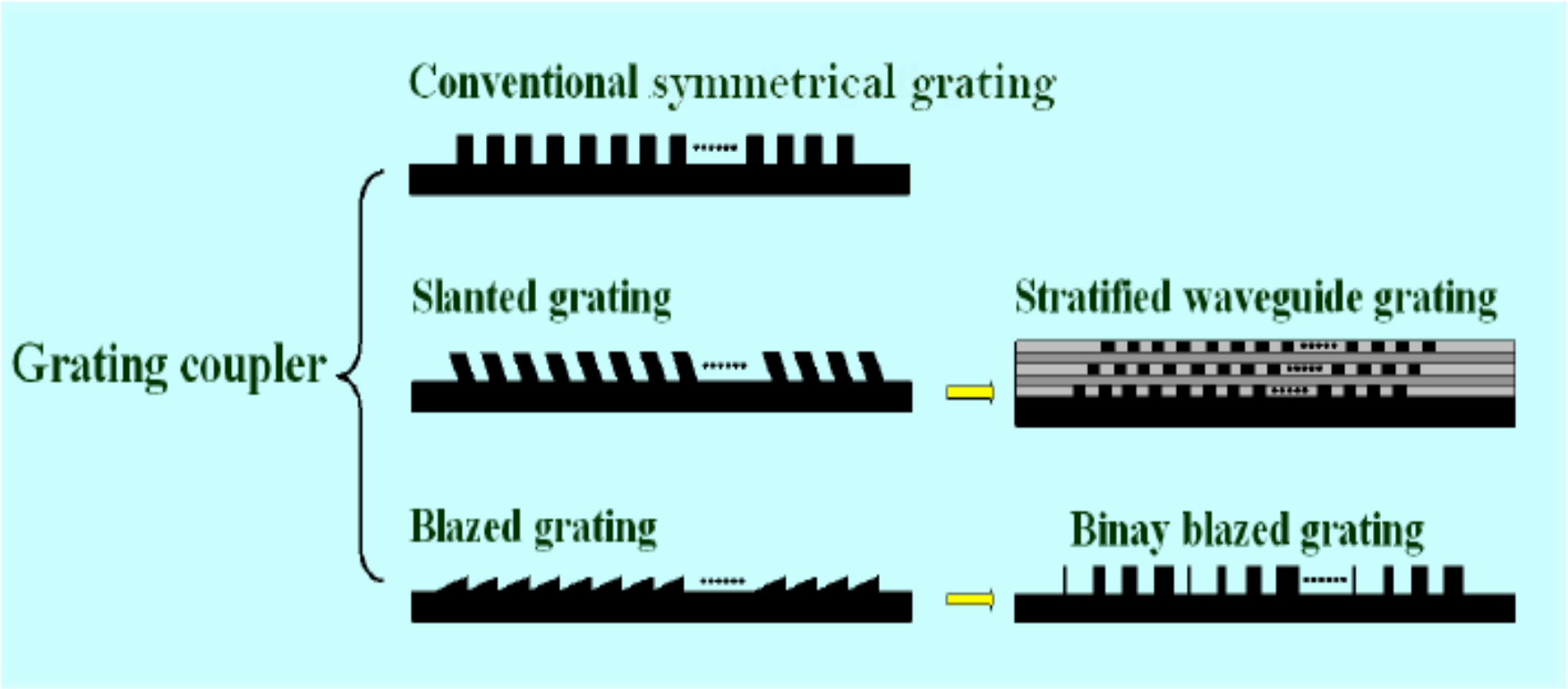
- *Xi'an: Investments totaling 3 billion yuan (US$360 million)* will go toward 40 projects, including a 364-hectare optoelectronics base.

Photonics cont'd

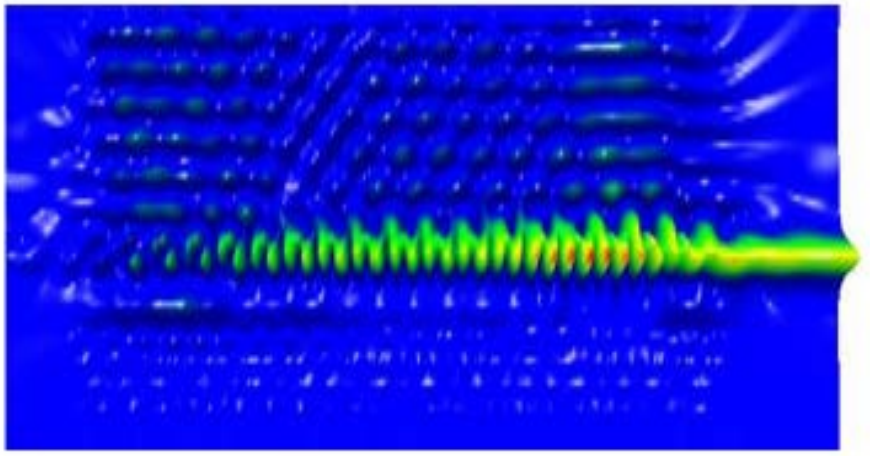
- *Shanghai: Within five to ten years, a large-scale, world class,* highly competitive optoelectronics base will be set up.
- *Zhejiang: Ongoing and planned projects have amassed over 1* billion yuan (US$120 million), among them, 17 projects involving investments of 900 million yuan (US$108 million).
- *Chongqing: 10 billion (US$1.2 billion) will be invested in* three phases to complete a China's Electronics Industry 2004 196 optoelectronics park. Within ten years, the park's turnover is expected to total 50 billion yuan (US$6 billion).

Grating Couplers for Silicon Photonics

- Grating couplers :
  - Can be placed anywhere;
  - No edge polishing needed;
  - Allow planar coupling (vertical coupling)



Binary Blazed Grating (BBG) Coupler



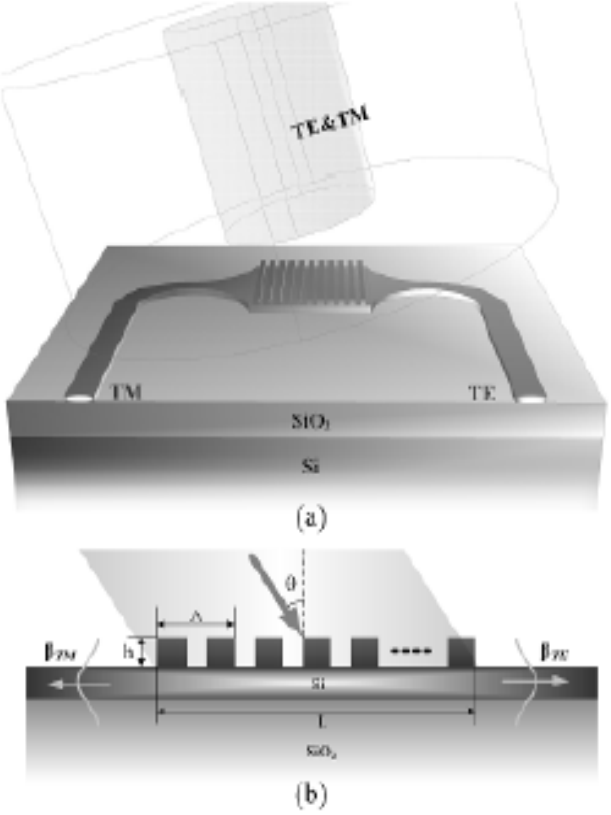
Grating length: 14μm

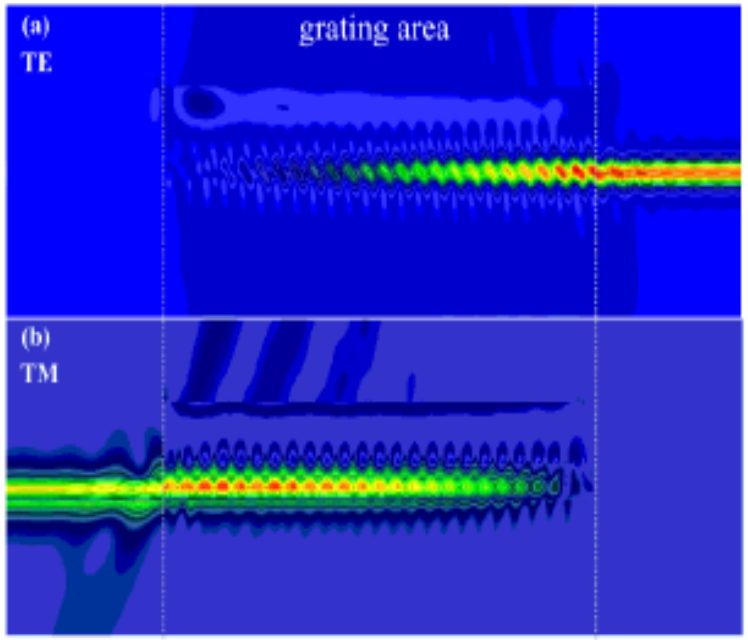
Coupling efficiency: 70%

3dB bandwidth: ~70nm

Polarization Splitter and Coupler

Efficient optical coupling and polarization splitter is proposed, as shown in Fig. The field distributions (E_x for TE polarization and H_x for TM polarization) are depicted, from which the polarization splitting behavior can be observed clearly.





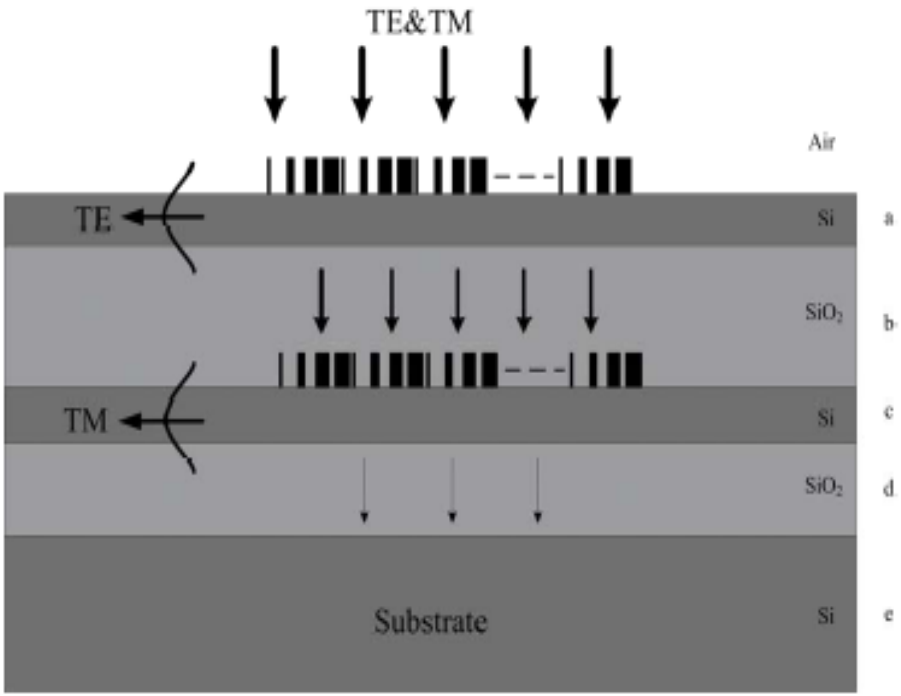
(a) Field distribution (E_x) for TE polarization; (b) field distribution (H_x) for TM polarization at 1550nm.

PBS based on BBG coupler

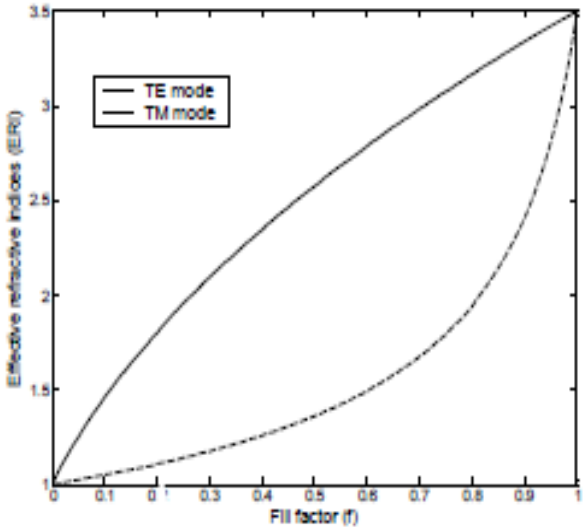
Polarization Beam Splitter (PBS)

$$n_{eff}^{TE} = [f n_g^{\,2} + (1-f) n_1^{\,2}]^{1/2}$$

$$\frac{1}{n_{eff}^{TM}} = [\frac{f}{n_g^{\,2}} + \frac{1-f}{n_1^{\,2}}]^{1/2}$$



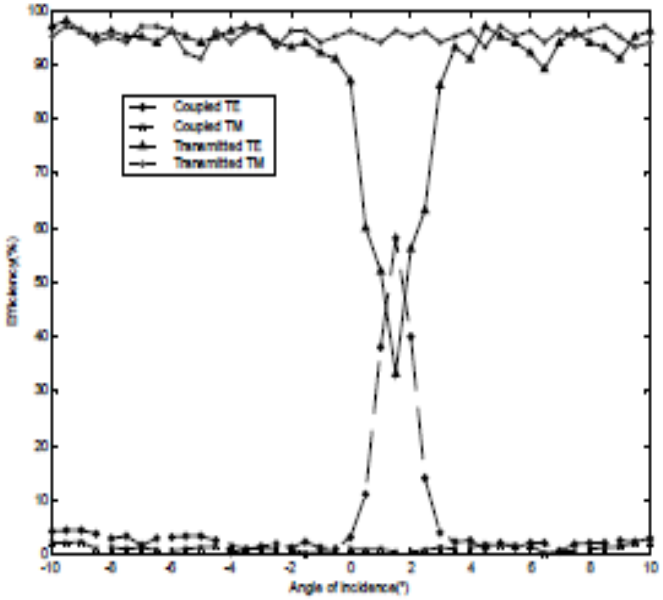
▲ Schematic of a two-layer grating coupler as a PBS.



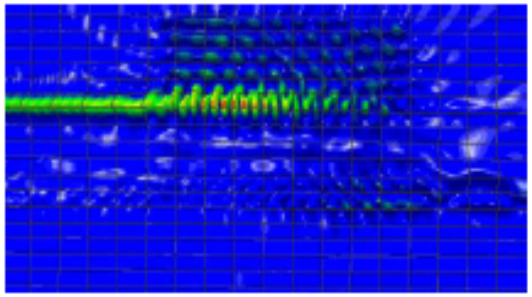
▲Effective refractive index differences between TE mode and TM mode as a function of fill factor, which may result in high extinction ratio between TE and TM modes

PBS based on BBG coupler

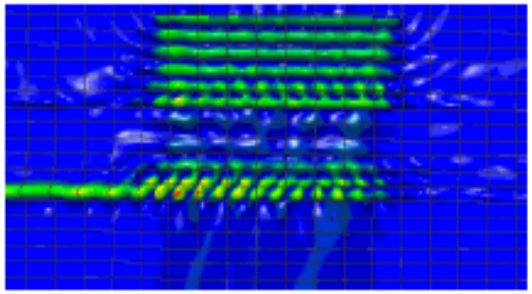
- Coupling efficiency
  - **58% for upper layer (TE)**
  - **50% for lower layer (TM)**
- Extinction ratio
  - **>20dB over 1530~1570nm**



▲Calculated values of coupled (dashed curve) and transmitted (solid curve) efficiencies of upper layer grating coupler for the TE polarization and TM polarization as a function of angle of incidence



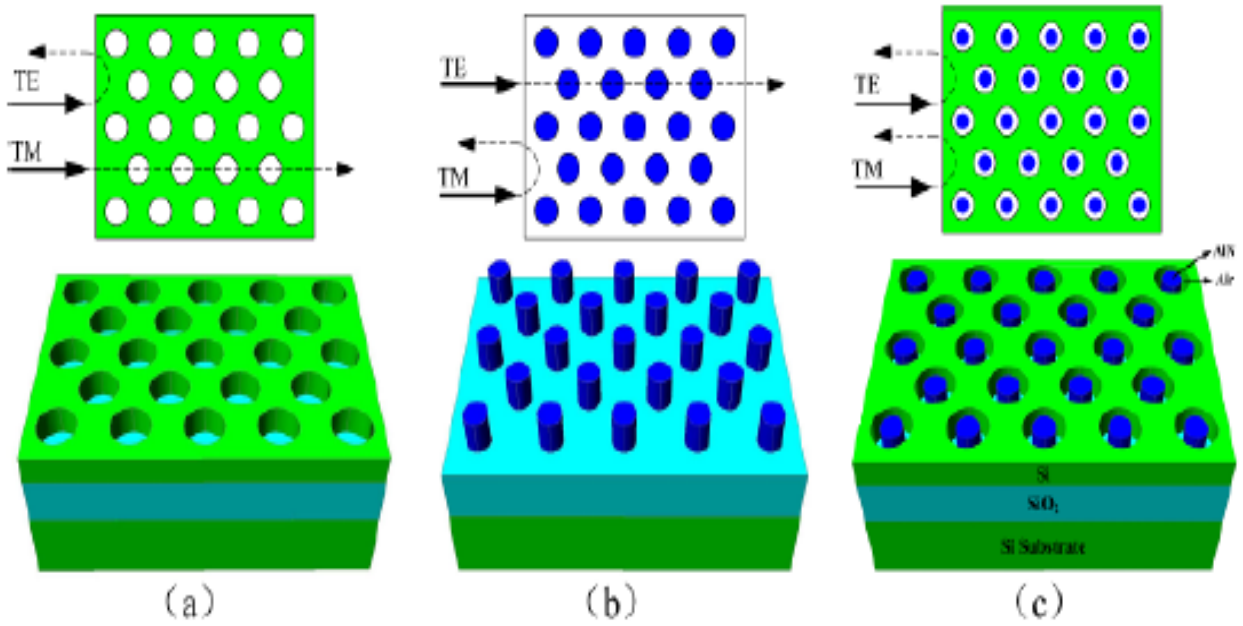
(a)TE input



(b) TM input

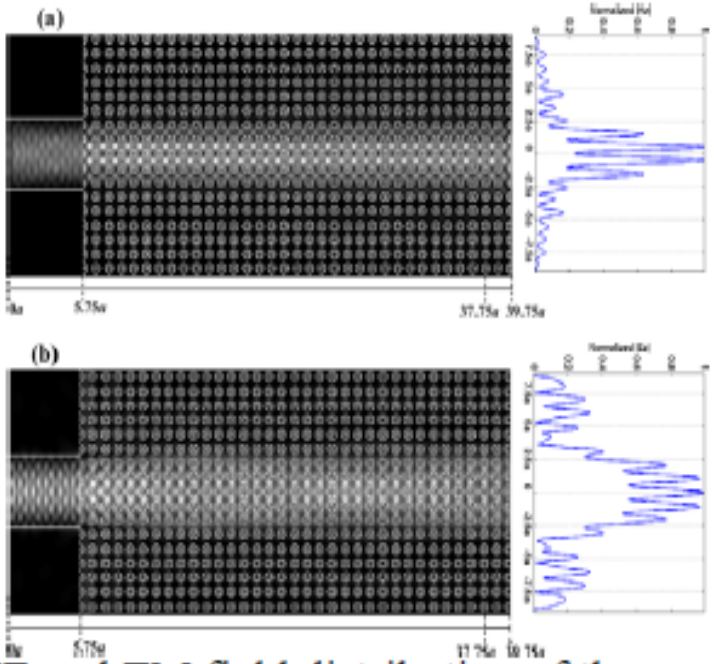
Annular Photonic Crystal Slab

The structure is made up of two types of materials. One part is dielectric background (a-Si) and the other part is the material used to obtain inner dielectric rods (Zr_3N_4). These two parts of the slab is detached from each other by the rings of air holes.

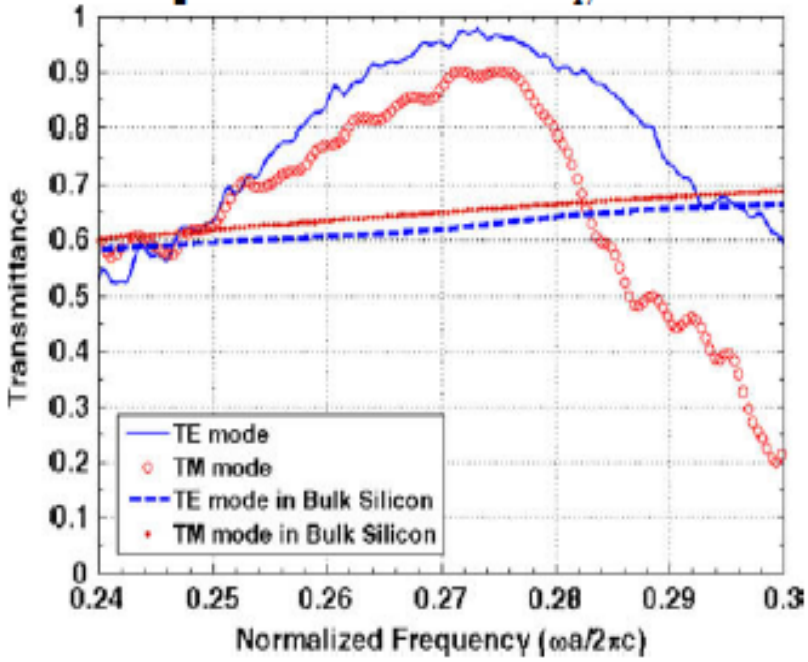


Air holes	Dielectric rods	Annular PCs
TE Bandgap	TE Bandgap	Both TE & TM Bandgap

Polarization insensitive self-collimation waveguide in square lattice annular photonic crystals



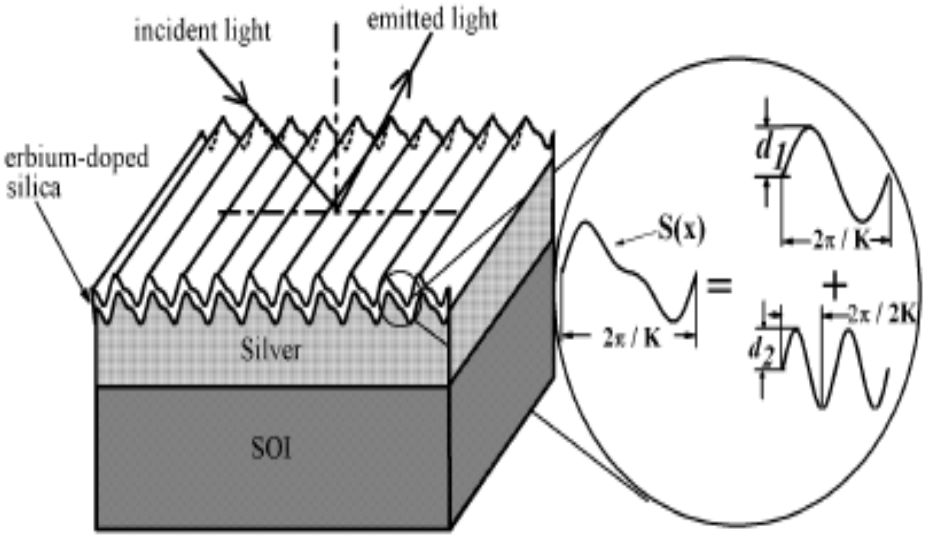
TE and TM field distribution of the simulation layouts with k = 1550 nm, (a) Hz field distribution for TE modes and (b) Ez field distribution for TM modes. The right figures show the normalized field amplitude profile of the beams at the position 37.5a.



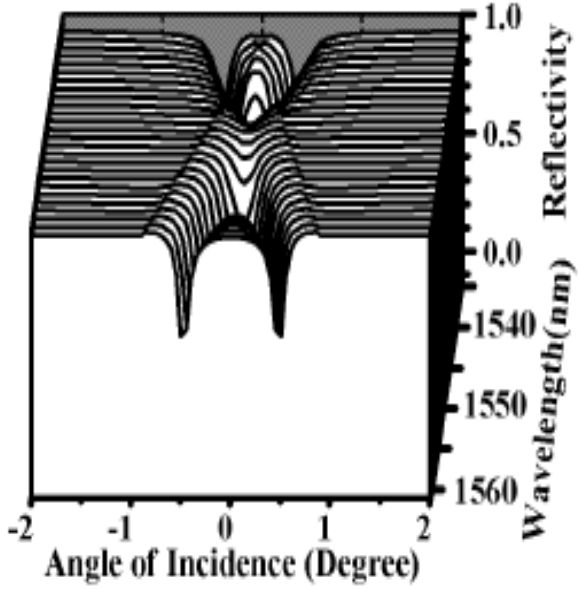
Spectra of SC annular PC waveguide and the spectra of bulk silicon for both TE and TM polarizations. A polarization insensitive waveguide is obtained in the normalized frequency range 0.262–0.280 with transmittance up to 80%, which corresponds to a frequency range 1500.4–1603.0 nm.

Enhanced Erbium-doped silica emission by using double metallic grating

The emission efficiency of erbium-doped silica at the wavelength of 1550 nm can be increased more than 10 times with the help of a double metallic grating (DMG) 。



Schematic diagram for erbium ion emission enhancement.



Reflectivity of the DMG as a function of both incident angles and wavelength.

Erbium silicate (Er_2SiO_5) and its application to waveguide amplifier and light source

Suitable conditions for light source:

CMOS-compatible

Transparent wavelength for silicon (>1.1 μm)

Electrical injection

High gain

Small size (L<1mm)

Silicon limits:

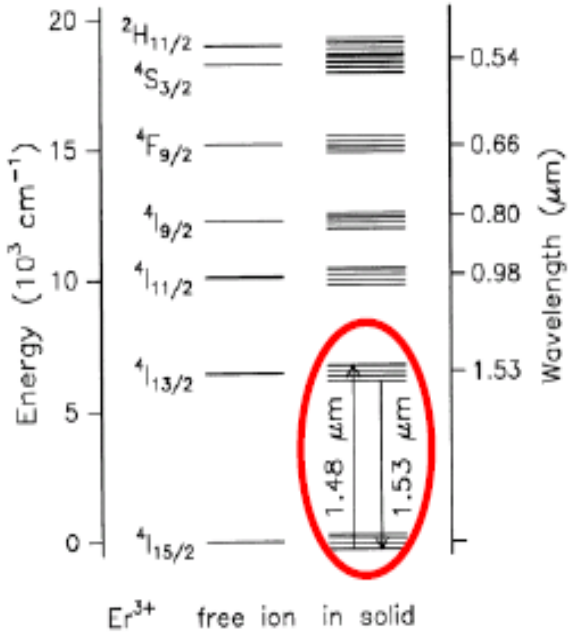
Indirect band gap

Efficient auger recombination

Free carrier absorption

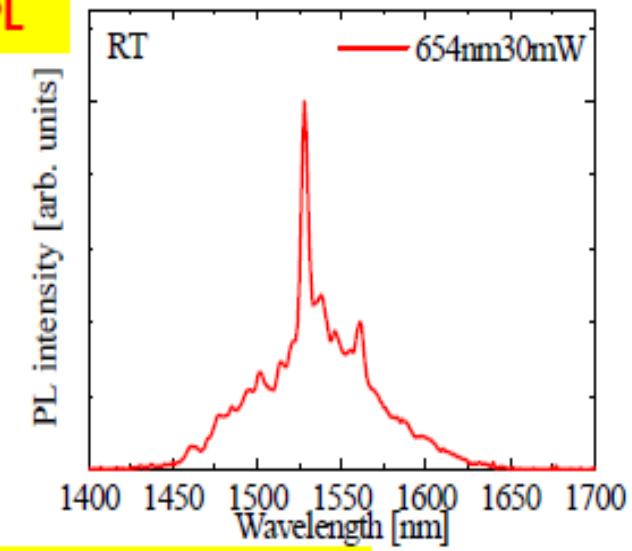
Rare earth (Er) doped silicon

(1.53 μm Communication wavelength)

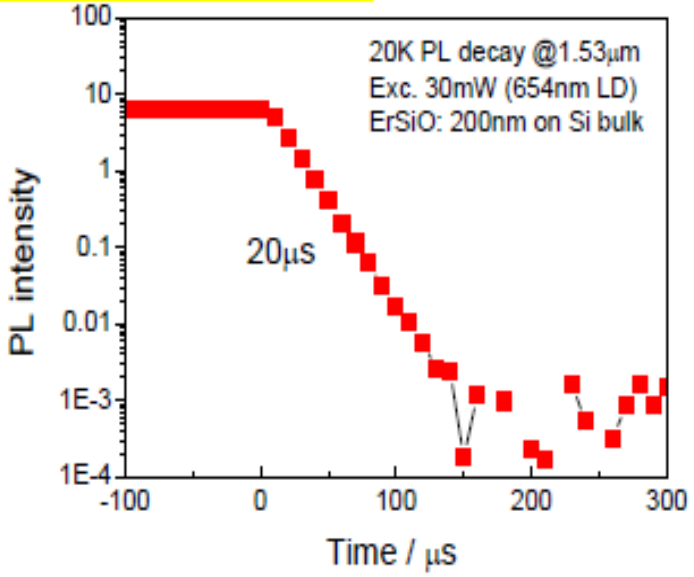


PL and decay time of Er_2SiO_5 structure at 20K and 300K

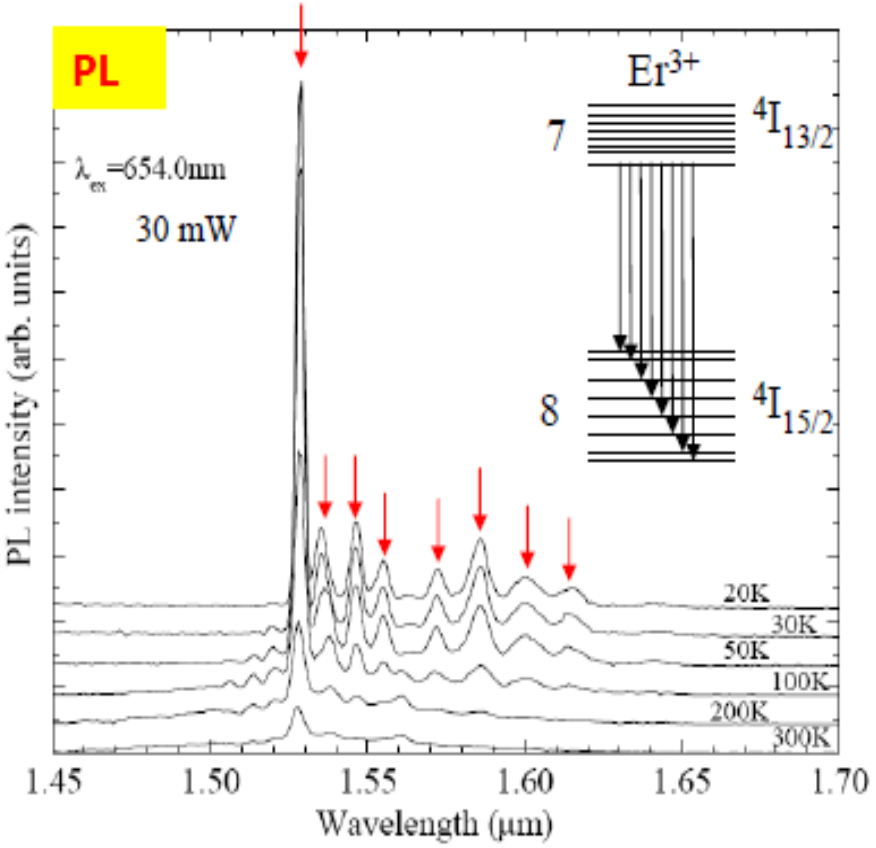
PL



Decay time



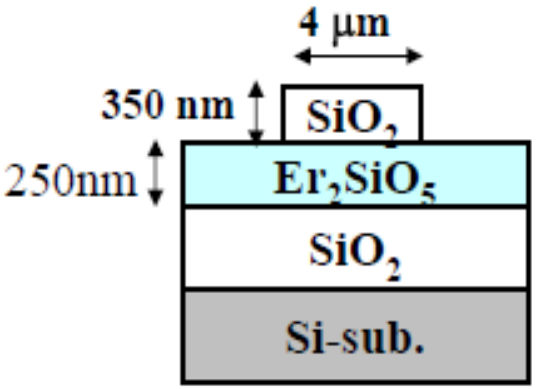
PL

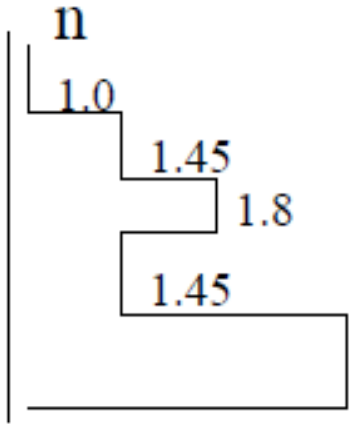


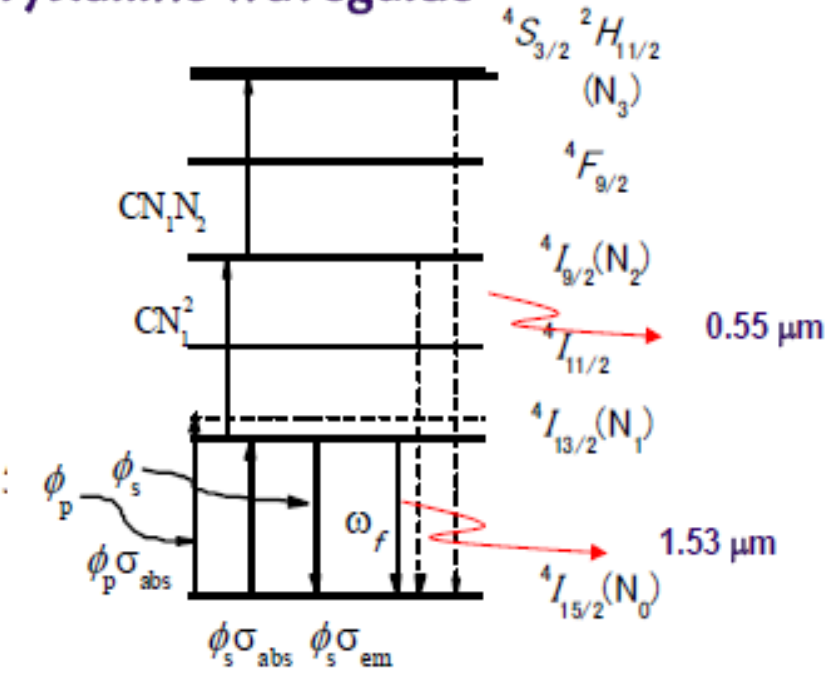
PL and decay time

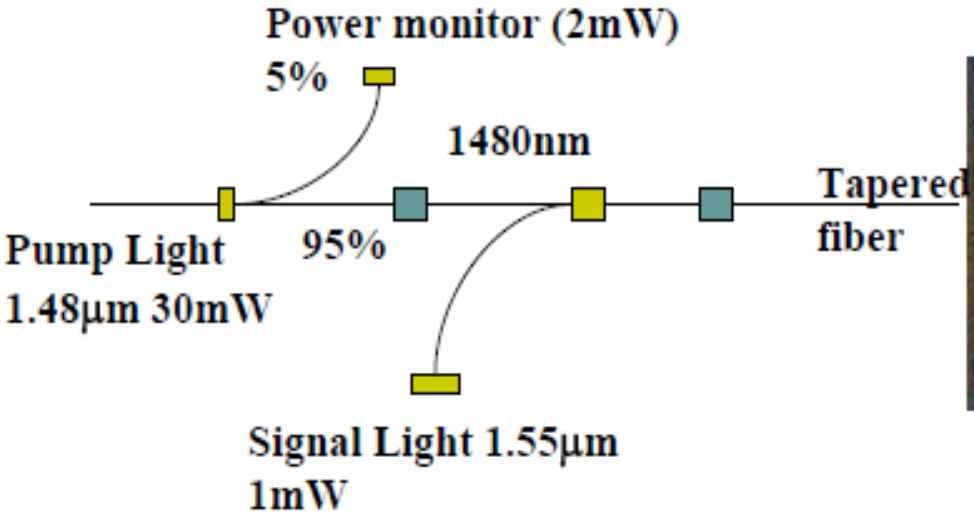
- PL fine structure (4meV@300K)(1meV@20K)
- Small thermal quenching (1/3 ~1/5)
- Small decay time quenching(0.5 ~0.8)
- Extreme short decay (20 μ s@20K)

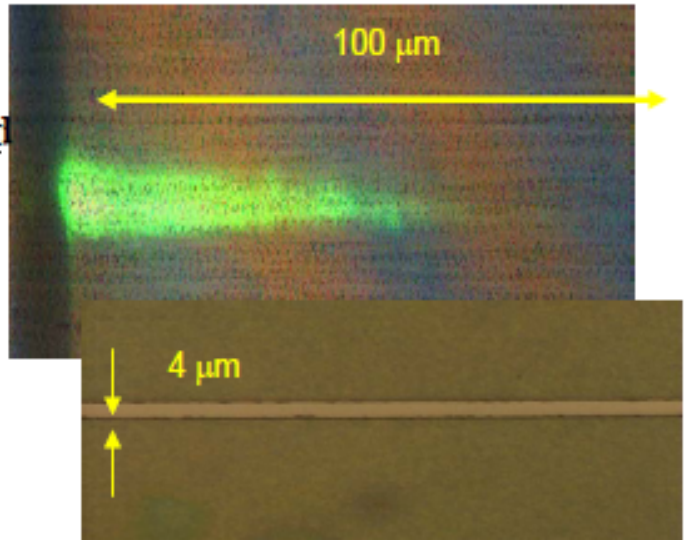
Evaluation and fabrication and of Er_2SiO_5 crystalline waveguide





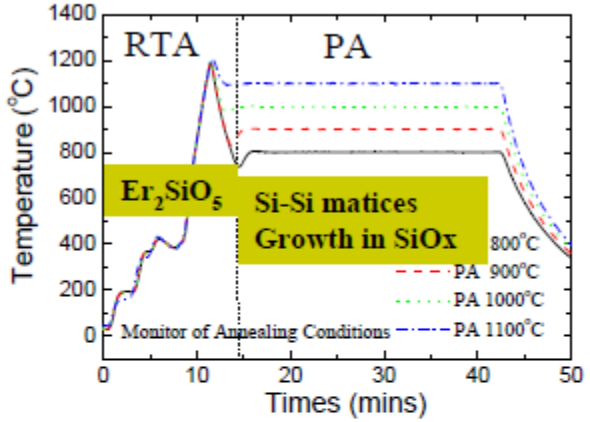


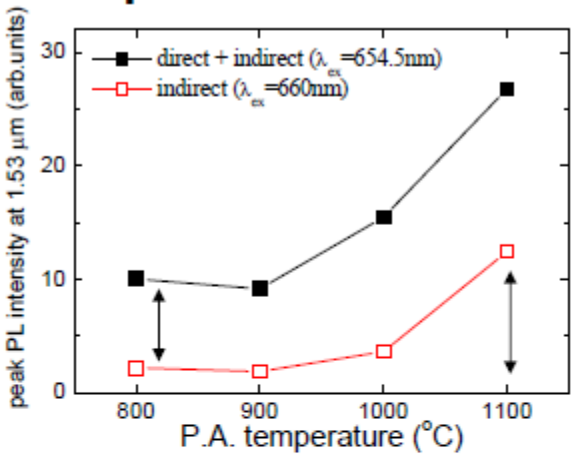




LED based on Er2SiO5/SRSO complex material

New annealing treatment process





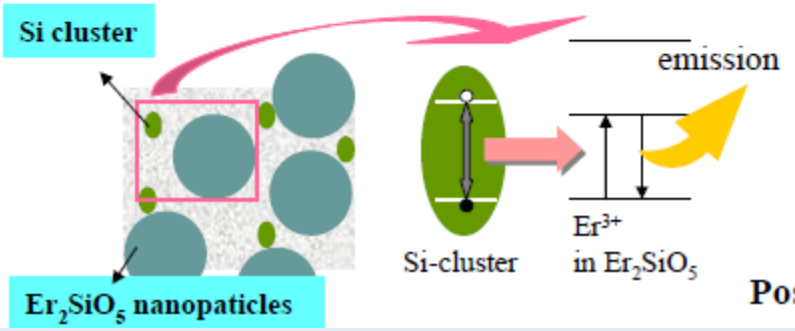
RTA: Nucleation of Er_2SiO_5 (1200 ℃)

PA: Formation of si cluster (800-1100 ℃)

Not effective to direct excitation emission

Indirect excitation increases above 1000 ℃

50% indirect excitation



Er_2SiO_5/SRSO complex material form

Indirect excitation

→ The possibility of excitation by carrier injection.

Possibility of Si based electrically pumped LED

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Joint Research Center of Photonics

聯合光子研究中心

- **JORCEP founded October 2003**
- **A model of Sino-European academic collaboration**
- **Enables KTH, LU and ZJU to stay at the forefront of Photonics research**
- **Mission**
  - Joint research
  - Joint PhD education
  - International Masters Program in Photonics

JORCEP @ Zhejiang University

Background

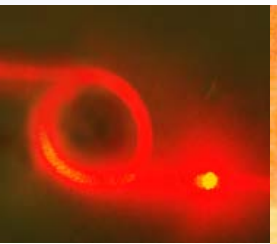
COER (Centre for Optical & Electromganetic Research) was established 10 years ago by Prof. Sailing He (received his PhD degree at KTH 20 years ago):

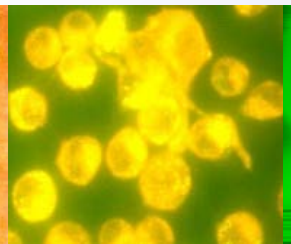
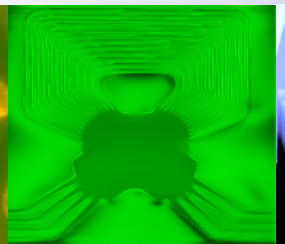
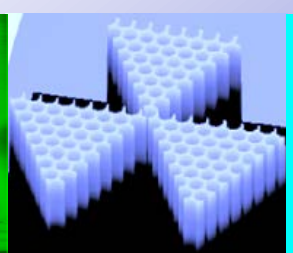
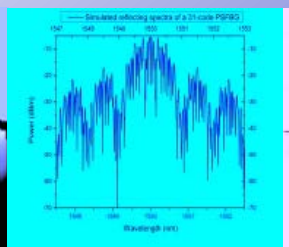
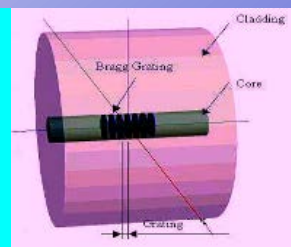
Faculty:

Profs (incl adjunct profs): 6
Associate Profs: 10
Post-docs: 4
PhD students: 50
Master students: 40

Research Areas:

- **Integrated photonics & nano-photonics**
- **Optical sensing technologies**
- **Artificial structured metamaterials**
- **Bio-photonics**
- **Optical fiber devices**
- **Optical communications**
- **Electromagnetics & microwave photonics**

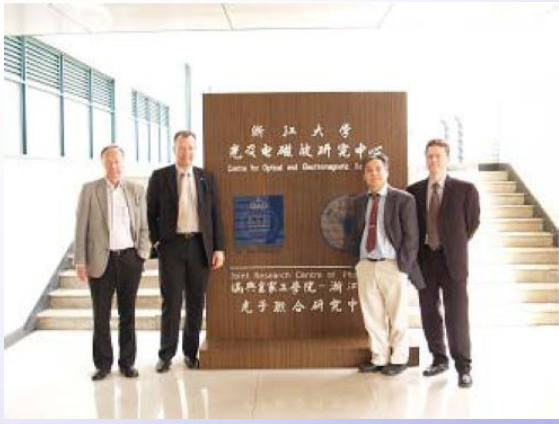


Staff

- Chief scientists
  - Prof. Sailing He (Director) , KTH & ZJU
  - Prof. Lars Thylén, KTH

  (Prof. Sune Svanberg of LU is joining the leadership)
- Deputy director – Assoc. Prof. Gabriel Somesfalean
- Senior admin. advisor – Assoc. Prof. Erik Forsberg
- Admin. assistant: Ms. Alexandra Högberg
- 27 faculty members associated to the center
- Staff exchange
  - 2 Swedish Assoc. Profs. working @ ZJU
  - 3 Chinese visiting scientist @ KTH
  - 2 Chinese post doc working @ KTH
  - 7 Chinese PhD students working @ KTH
  - 4 ZJU exchange PhD students @LU
  - 3 Swedish MSc student working @ ZJU (during 2008)
  - Numerous short term research visits of senior staff



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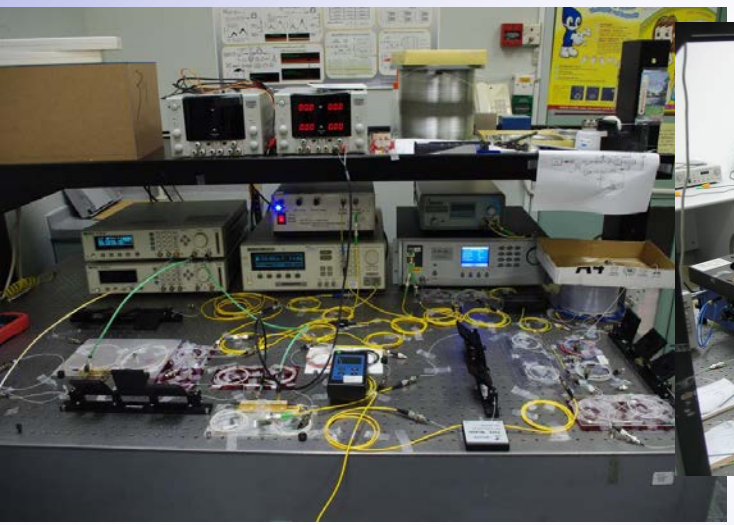
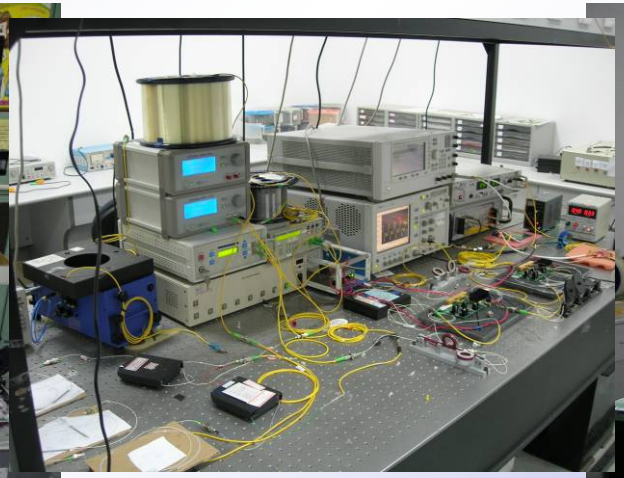
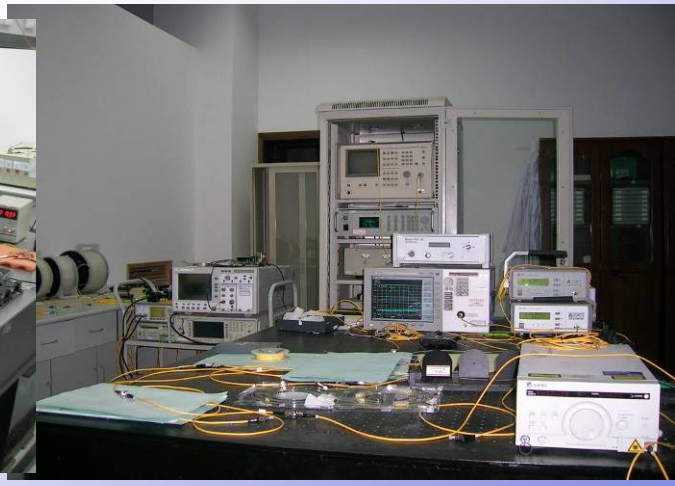
Measurement platform







Ph.D. Education

- Large exchange of students
  - Mostly from China to Sweden (CSC)
  - More Swedish students to China needed
- Joint courses in the future

Int'l M.Sc program in Photonics

- Started fall semester 2005
- Students spend time both @ ZJU and @ KTH
  - 1+1 year + MSc project in Sweden or China
- Based on existing MSc in Photonics Program @ KTH
  - Established curriculum (Erasmus Mundus)
  - Experienced teachers (mainly from KTH)
- Students receive double degree from KTH – ZJU
- Students attractive on the international photonics job market
- 80% of graduated students so far are now pursuing their PhD in Europe
- Currently in revision

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Joint Research Center of Photonics

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Joint Research

Focus areas

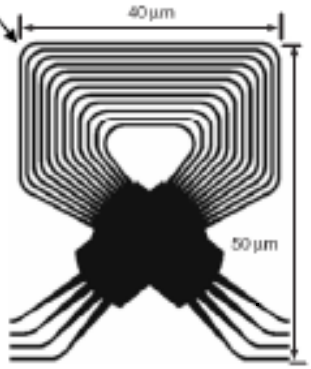
- **Research topics:**
  - Nanophotonics and integrated lightwave circuits
  - Metamaterials
  - Biophotonics
  - Optical communication networks
  - High speed modulators
  - Optical sensing
- **Interdisciplinary research project**
  - Large biophotonics effort in collaboration with Kista Photonics Research Center, Albanova, Karolinska Institute & Zhejiang University
- **Publications in the name of the center**
  - over 160 papers in international journals

Compact Arrayed Waveguide Grating Demultiplexers Based on Amorphous Silicon Nanowires

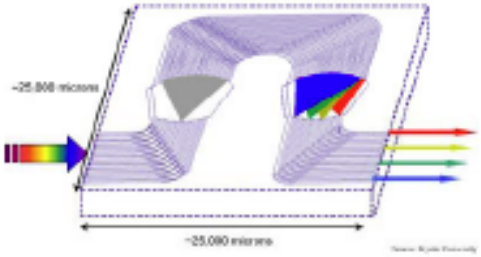
our AWG demultiplexer based on Si nano-waveguides

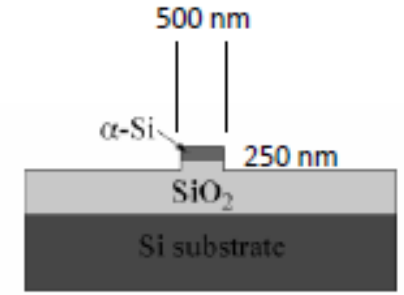
Our novel layout: overlapped FPRs
(D. Dai and S. He, IEEE JSTQE , 12(6), 1301, 2006).

sharp bending



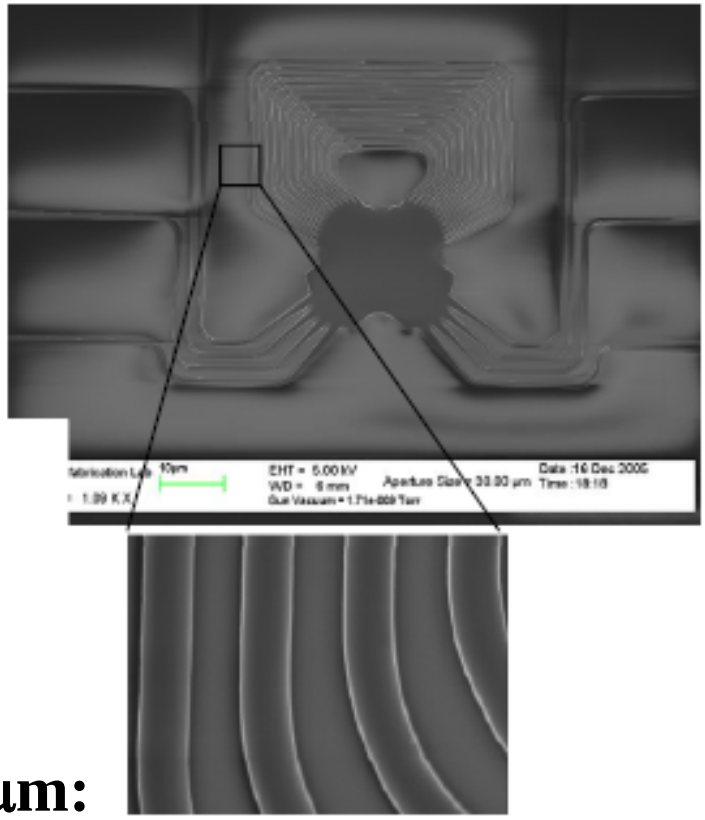
30,000 times smaller than a conventional SiO2 AWG:





5μm

our fabricated AWG



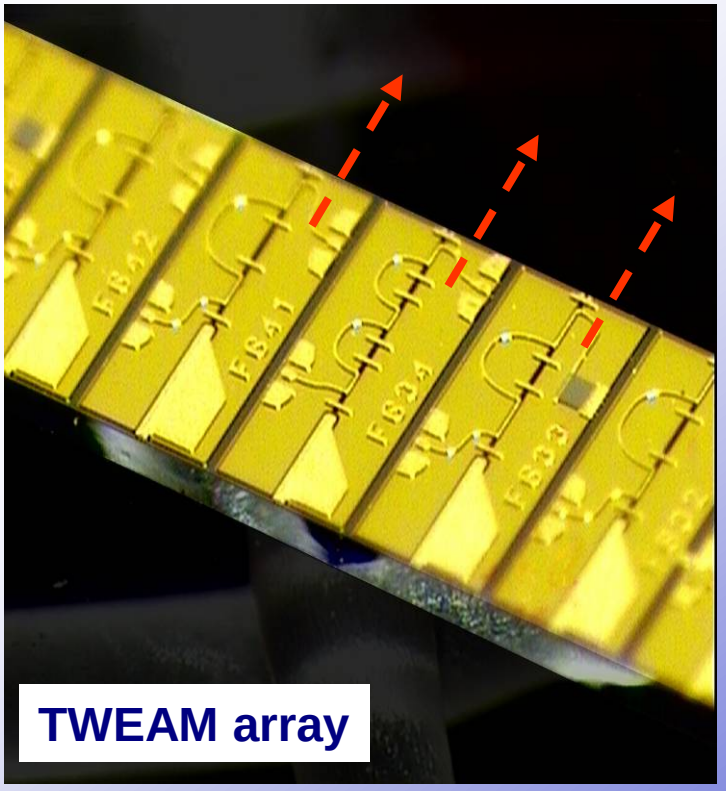
40 μm x 50 μm:
smallest in the world

D. Dai, L. Liu, L. Wosinski and S. He, Electronics Letters, 42(7): 400-402, 2006.

Traveling-Wave Electroabsorption Modulators

Light-intensity modulators for future fiberoptical datacommunications at 100Gb/s

>90GHz
world-record bandwidth



Yu YC, Karlsson S, Liu CP, Schatz R, Westergren U, Kjebon O, Chuang CH, He SL, Thylen L, Krysa AB, Roberts JS, Seeds AJ,
IEEE PHOTONICS TECHNOLOGY LETTERS, 18 (5-8): 770-772, MAR-APR 2006.

2 joint PhD theses completed on this subject

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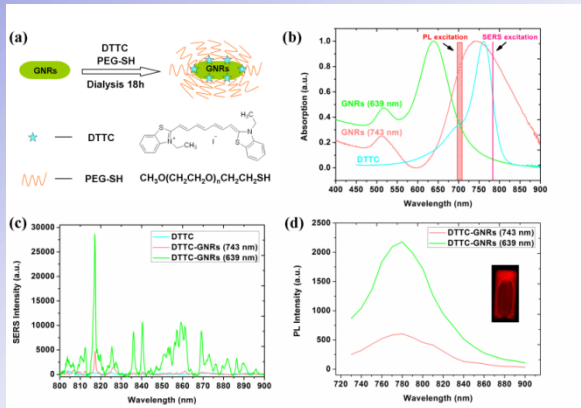
Novel Nanoparticles for Optical Biomedical Applications

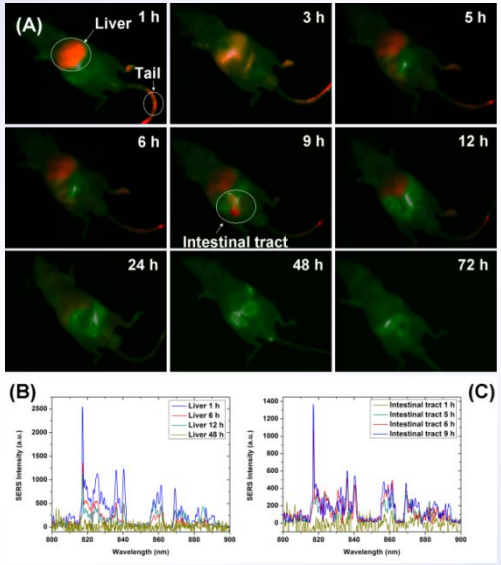
—— Supported by the Swedish Foundation for Strategic Research (SSF)

J. Qian, *et. al,* "Fluorescence-Surface Enhanced Raman Scattering Co-functionalized Gold Nanorods as Near-infrared Probes for Purely Optical *In vivo* Imaging" Biomaterials (IF=7.365), 2010.

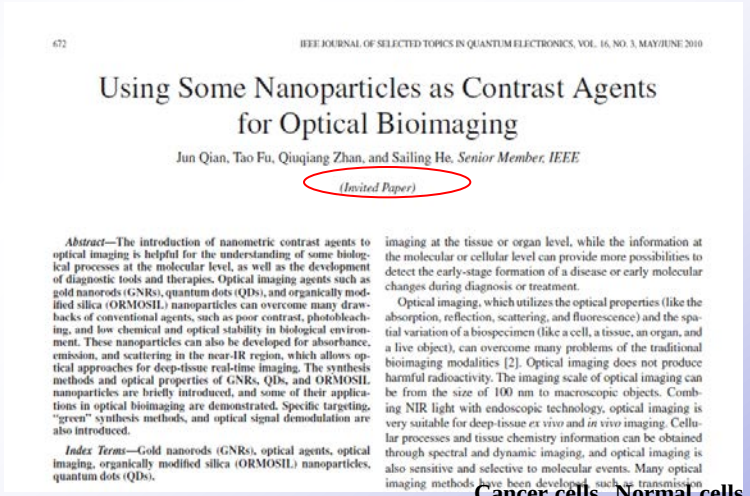
J. Qian, *et. al,* (invited paper), IEEE Journal of Selected Topics in Quantum Electronics, 16 (3) 672-684 (2010).



Synthesis and optical characterizations of Fluorescence-Surface Enhanced Raman Scattering Co-functionalized GNRs



NIR fluorescence and surface enhanced raman scattering signals were used to track the distribution and clearance of GNRs in animal body



672 IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS, VOL. 16, NO. 3, MAY/JUNE 2010

Using Some Nanoparticles as Contrast Agents for Optical Bioimaging

Jun Qian, Tao Fu, Qiuqiang Zhan, and Sailing He, *Senior Member, IEEE*

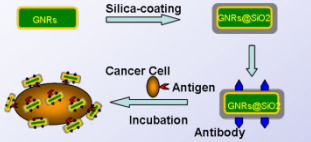
(Invited Paper)

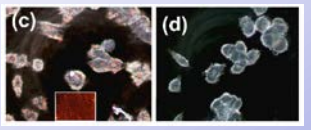
***Abstract*—The introduction of nanometric contrast agents to optical imaging is helpful for the understanding of some biological processes at the molecular level, as well as the development of diagnostic tools and therapies. Optical imaging agents such as gold nanorods (GNRs), quantum dots (QDs), and organically modified silica (ORMOSIL) nanoparticles can overcome many drawbacks of conventional agents, such as poor contrast, photobleaching, and low chemical and optical stability in biological environment. These nanoparticles can also be developed for absorbance, emission, and scattering in the near-IR region, which allows optical approaches for deep-tissue real-time imaging. The synthesis methods and optical properties of GNRs, QDs, and ORMOSIL nanoparticles are briefly introduced, and some of their applications in optical bioimaging are demonstrated. Specific targeting, "green" synthesis methods, and optical signal demodulation are also introduced.**

***Index Terms*—Gold nanorods (GNRs), optical agents, optical imaging, organically modified silica (ORMOSIL) nanoparticles, quantum dots (QDs).**

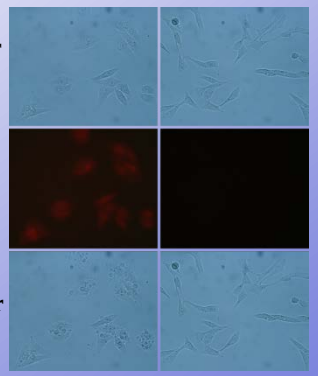
imaging at the tissue or organ level, while the information at the molecular or cellular level can provide more possibilities to detect the early-stage formation of a disease or early molecular changes during diagnosis or treatment.

Optical imaging, which utilizes the optical properties (like the absorption, reflection, scattering, and fluorescence) and the spatial variation of a biospecimen (like a cell, a tissue, an organ, and a live object), can overcome many problems of the traditional bioimaging modalities [2]. Optical imaging does not produce harmful radioactivity. The imaging scale of optical imaging can be from the size of 100 nm to macroscopic objects. Combing NIR light with endoscopic technology, optical imaging is very suitable for deep-tissue *ex vivo* and *in vivo* imaging. Cellular processes and tissue chemistry information can be obtained through spectral and dynamic imaging, and optical imaging is also sensitive and selective to molecular events. Many optical imaging methods have been developed, such as transmission





Silica functionalization of GNRs for bioconjugation with antibody and further dark field light scattering imaging of cancer cells.



Photosensitizer-doped silica nanoparticles for photodynamic therapy (PDT) of cancer cells

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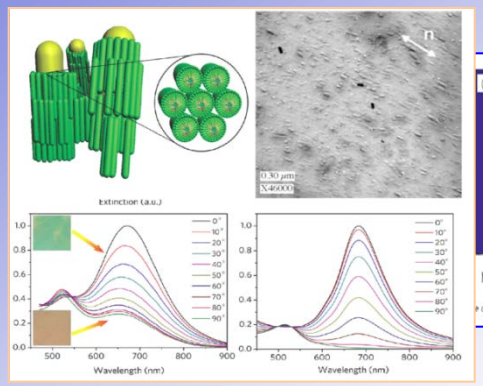
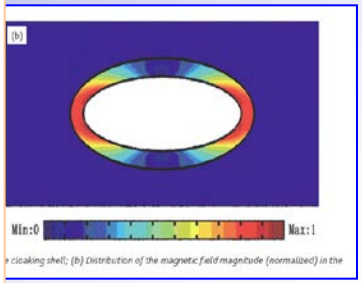
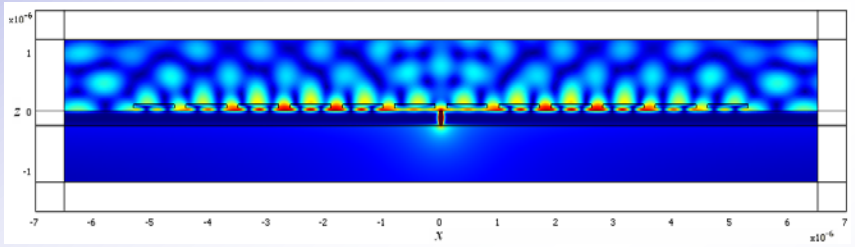
Optical nano antennas for improving the performance of organic solar cells

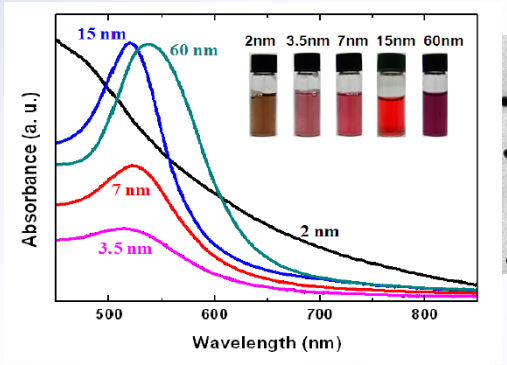


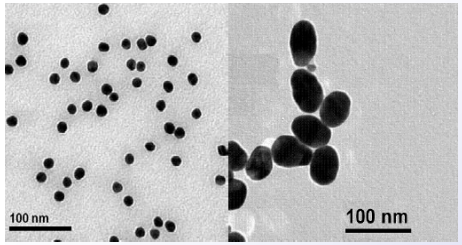


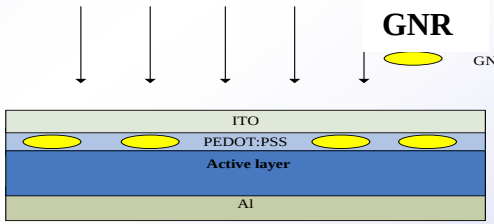


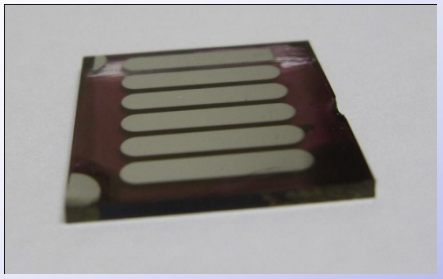
Sailing He, et. al, "Optical Nanoantennas and Metamaterilas," Materials Today (IF≈13), 12 (12), Pages 16-24, 2009.

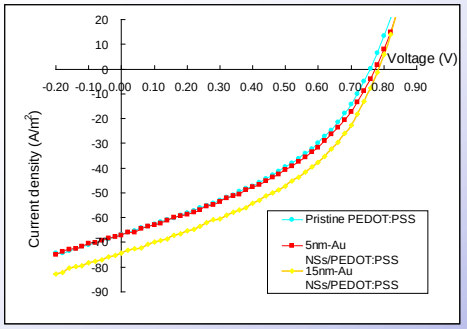
Q. Liu, et. al, Nano Lett. (IF≈10), 10, 1347–1353, 2010











L. Qiao, et. al,
Applied Energy , 88, 848–852, 2011

we have improved the efficiency of a solar cell (ITO/PEDOT/MEH-PPV:PCBM/Al) from 3.10% to 3.97%: improved by 28% !

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Joint Research Center of Photonics

Win-win

- **Sweden**
  - Talented students from China (e.g. CSC scholarships)
  - Larger research volume due to collaboration
  - Access to Chinese photonics research community

- **China**
  - Access to advanced know-how and processing technology
  - Access to international contact network

Thank you

Sammanfattning av preliminära resultat

- Hög genomsnittlig citering av svensk-kinesiska sampublikationer
- Få svenskar studerar / forskar i Kina
- Främst stora svenska företag som har FoI-närvaro i Kina
- Kinesiska FoI-dotterbolag i Sverige inom IKT, Life science och fordon
- Vikten av medvetenhet om möjliga konkurrenssituationer mellan Sverige/EU och Kina
- Vikten av professionell hantering av avtal och IPR-frågor
- Kan vara svårt att etablera de rätta kontakterna och identifiera lämpliga aktörer/partner för samarbete i Kina
- Initiala kontakter, möten och resor kostar
- Vikten av att ta tillvara erfarenheter
- Kinastrategi / internationell strategi