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Testimony before the U.S.-China Economic and Security Review Commission
China's Industrial Policy and its Impact on U.S. Companies, Workers and the American Economy

I would like to thank the Commission for this opportunity to share my grave concerns over our future competitiveness in key technologies that are vital to our future prosperity. My career has mostly been in the technology industry, leading companies that supplied innovative products and tools to researchers in industry, academia and medicine, and to product integrators for high technology applications. Since 1999 I have been CEO of SPIE, a not-for-profit membership society. SPIE has approximately 17,000 members, most of whom have advanced degrees in science or engineering. More than 50% of our 10,000 U.S. members work in industry. Most of the remainder work in academia and the various government science and technology entities, such as the national laboratories, NASA, NIST, and the many excellent Department of Defense facilities.

Professional associations have played an important and undervalued role in the U.S. and global science and technology (S&T) enterprise. This role is similar to the important role of the legal system in underpinning civilization; they underpin science. Our imprimatur and archiving are fundamental to scientific progress, and we continue the important struggle to keep the internet version of snake oil salesmen from drowning us in pseudo-science. Many engineering associations set technical standards without which we would not have a practical technical infrastructure, and unproductive chaos rather than the quality of life that technology has brought. In a reductio ad absurdum example, imagine a world with multiple versions for the colors of traffic lights.

The fact that the strongest scientific associations are based in the U.S. has been good for U.S. science. The networking at meetings and the historic pattern of the top international scientists coming to and presenting at meetings staged by associations in the U.S. has given our community an edge. The exchange and testing of ideas at such events is at the heart of scientific advance. At SPIE's meetings, postgraduate students network with Nobel laureates and industry experts. We just wish there were more U.S. students exposed to these life-influencing opportunities.

Scientific associations in China

China has about 170 scientific societies or associations which are supervised by the Chinese Association of Science and Technology (CAST). CAST has a permanent staff of 1,000 throughout China and a conference/exhibit facility in Beijing. The effective head of CAST operations is Executive Vice President Deng Nan, daughter of former premier Deng Xiao-Ping. The scientific societies in China are highly academic and have large numbers of nominal members, but are not yet staffed or resourced to provide effective networking or services to members. For example, the Chinese Optical Society, the largest and most directly focused of several in the optoelectronics field, has at this stage very poor connections with industry. The reality is that in China, academic science is disconnected from industry research, and many Chinese scientists look to the U.S. as one of the few nations that have the strong connections they seek.

However, China has the powerful Chinese Academy of Sciences (CAS) that links together and controls many Chinese scientists. The CAS operates many of the larger research laboratories through the country and has an extensive campus in Beijing. Unlike most academies of science worldwide the CAS has an emphasis on manufacturing and technology with “Advanced Manufacturing Technology and Automation Technology” listed alongside the “Physical Science and Related Technology, Life Sciences and Technology etc.” The mention of “technology” is in itself unusual for an academy of science.

SPIE: Science and Industry

There is another very important component of our membership that distinguishes SPIE somewhat from the typical scientific association. We embrace and acknowledge the entrepreneurs, the marketers and the manufacturers who turn research into innovation, whose living depends on knowledge of the science, and whose practicality turns it back into jobs. We run many large technical meetings that are designed to catalyze photonic science and its applications. At our Photonics West meeting in California in January we had more than 1,000 exhibiting companies from all over the world. We will have more than 500 companies at our upcoming meeting in Florida: Defense, Security and Sensing (another annual event). These are not trade shows; at these meetings there are more than 6,000 technical presentations. We have an earned reputation for connecting the disparate multidisciplinary research community with the commercial and user communities. To us the commercialization of science and the success of technology industries are vital to a healthy scientific infrastructure. They provide careers for S&T professionals and the bulk of funding for innovation.

Optoelectronics

Optoelectronics, the subject of the present hearing, is loosely defined and also known as photonics, optics, electro-optics, and optical engineering. Each name for the field has various nuances but I see too much passion for each name to expect agreement. Whatever the name, the field is vast and the technology key to the many sectors of a high technology economy. It covers the fabrication and inspection of computer chips to surveillance equipment, imagers and displays for the health field, cameras and displays for the consumer market, and much more. The internet is optically powered; your DVD player houses a laser and light detectors, the fundamentals of optoelectronics. Most medical diagnostic equipment has significant optoelectronics buried inside, and presents the grisly details on an optoelectronic display. Many researchers use optoelectronic tools unaware that they are using optics or light. ”Reading” DNA relies on high performance optoelectronics, but the typical geneticist gives it no more thought than she does to the optical lithography that made her computer’s powerful processor and memory chips.

The field SPIE (and optoelectronics) covers is light. Experts in optoelectronics look at how to best convert sunlight into electrical power or some other form of usable energy, such as liberated hydrogen. Photovoltaics are already well known, but not optimized, and perhaps even not the ultimate solution. Lighting, conversion of initially gas and then electricity into light, has changed the world. A century after Edison, there is a huge worldwide effort to make lighting more efficient, and China is among numerous countries that have identified the economic potential of solid state lighting (LEDs).

Edison's story is instructive on the commercialization and exploitation of science. He was not a scientific leader in light or lighting. Rather, he was someone with the drive, the single-mindedness, and the persistence to create and dominate a market. Today I only find that type of focus in Asia, and indeed see very successful exploitation of science there that was funded by taxpayers in the U.S. and Europe.

Workforce: The talent wars

I recently watched SPIE's video interview with Kristina Johnson, a former SPIE Board member and current nominee for undersecretary at the Department of Energy.

http://mfile.akamai.com/65904/mov/spiestorage.download.akamai.com/65904/KristinaJohnson.mov

She mentions that she went into the field largely because her father was an electrical engineer. Informal surveys of our U.S. based members suggest that many do not recommend the profession to their children. Figure 1 shows the trend in electrical engineering PhDs awarded in the U.S. PhDs are a necessary (but not sufficient) part of our innovation infrastructure. We have been fortunate that over the years many of those who came here for an education stayed and helped sustain our economy. However, relying on historical trends in this regard would be foolhardy. We were the most attractive home for China's best and brightest when we boasted the leading high tech economy, and when the alternative was to return to a nation with an impoverished and dysfunctional S&T enterprise damaged during the anti-intellectualism of the Cultural Revolution. The days when we could rely on imported brain power are gone. The economic picture makes us less attractive in general for those who have a choice of options. More Chinese students now go to the EU than to the U.S.

In the S&T talent stakes, the emphasis by the Chinese leadership on S&T and the obvious commitment to build a world class presence in S&T has changed the pattern. Chinese students still go abroad in large numbers, but China seems willing to invest heavily in luring back top scientists. In January the Chinese Academy of Sciences (CAS) gave a boost to their longstanding efforts to recruit expatriate talent and with them the knowledge and expertise of many of the world's top laboratories.

"The CAS announced the plan only days after a guideline was issued by the General Office of the Communist Party of the China Central Committee, calling on state enterprises and academic institutions to attract more leading overseas scientists, especially those on the cutting edge of science and technology."

http://english.cas.ac.cn/eng2003/news/detailnewsb.asp?InfoNo=27559

The "hai gui" ("sea turtles") were already returning in increased numbers before this latest inducement (Fig. 2).

I suspect the timing of the CAS announcement is deliberate, as the recession has stirred concern for the future in many. *Business Week* of March 16th has an article titled "America's Immigrant Brain Drain" written by Vivek Wadhwa who holds appointments at Harvard and Duke, and who is well published on the talent wars.

"Immigrants are critical to our long-term economic health. Although they represent just 12% of the U.S. population, they have started 52% of Silicon Valley's tech companies and contributed to more than 25% of U.S. global patents. They make up 24% of science and engineering workers with bachelor's degrees and 47% of those with PhDs.

Now, say human resources directors in India and China, what was a trickle of returnees a decade ago has become a flood. (There are no official numbers on the reverse migration.) Job applications from immigrants in the U.S., they say, have risen tenfold over the past few years."

Wadhwa quotes the results of a 2008 survey of 1,203 returnees to India and China. His team at Duke conducted this survey with AnnaLee Saxenian of the University of California at Berkeley and Richard B. Freeman of Harvard University.

"The vast majority of returnees, we found, are relatively young—30 on average for Indians, 33 for Chinese. Their degrees are in management, technology, and science. Among the Chinese, 51% have MAs, 41% PhDs. Among Indians, 66% hold MAs and 21% are PhDs. These figures put the returnees in the U.S. population's educational top tier—precisely the kind of people who can make the greatest contribution to innovation and growth."

Of course there are many who do not return to China. There are other ways of absorbing foreign expertise. For example, Chinese institutions welcome western-based Chinese scientists with faculty appointments in China. I know of several in my own limited circle, one of whom has a full time job leading research in a U.S. lab, and who supervises PhD candidates through his faculty appointments at two different Chinese universities, one in Beijing and one in Shanghai.

The Shanghai Jiao Tong rankings of world universities lists only one (mainland) Chinese university in the top 50 in the engineering category, and none in science. Tsinghua University in Beijing, sometimes called China's MIT, is ranked #50 in the latest engineering ranking. What is striking though is the rate at which Chinese universities are moving up in the annual science and engineering rankings.

There are obstacles for those Chinese scientists and engineers who stay here in the U.S. One factor covered well in the recent report "Beyond Fortress America" (and aired extensively in the Congressional hearings in February) is the restriction on foreign nationals studying or conducting research in the U.S. While there are very legitimate security concerns, the atmosphere generated by the present regulations and the bureaucratic burden placed on universities and other research institutions in the U.S. are also reasons that we should not expect the historic level of contribution to our S&T capacity from Chinese scientists coming to and staying in the U.S. A group leader at Cal Tech's Jet Propulsion Laboratory (JPL) told me last year that although quite often the best applicants for openings in this important laboratory are Chinese émigrés, he no longer considers them because the hiring and monitoring requirements are too onerous, and incompatible with the openness that characterizes a productive scientific environment. The unwelcome outcome is that some of our leading national facilities may tend to be staffed by second tier candidates.

China

The Chinese Ministry of Science and Technology (MOST) is the prime mover in China's S&T. MOST clearly sees science as important to the economy and sees its mandate as much more than increasing scientific knowledge. From the 863 plan, one of the series of five year plans for Chinese S&T:

"**Mega-projects of Science Research for the 10th Five-Year Plan**

To meet new challenges and demands after China's WTO accession, and cater to domestic strategic economic restructuring, the Ministry of Science and Technology, with the approval of the 10th session of the State Science and Education Steering Group, has decided to organize and implement 12 mega-projects of science research based on the 863 Program and the National Key Technologies R&D Program. Through the implementation of dedicated projects, the Ministry hopes to take favorable positions in the science frontier in the 21st century ***and achieve significant technical breakthroughs, leading to industrialization in major fields related to national socio-economic development, all within 3 to 5 years.***

Implementation Guidelines for the 12 Mega-projects are:

Goal: ***Develop new products and nurture new industries"***

One of the four scientists who devised the 863 plan is Wang Daheng, widely revered as the father of optics in China. Dr. Daheng studied in the UK. The technical background of Cao Jailin is also in optics; he is Vice President of the Chinese Optical Society as well as the Vice Minister of Science and Technology. These may indicate the importance of optics or optoelectronics in China.

Again showing the official view of the role of scientists, Chinese Premier Wen Jiabao, when presenting awards to Chinese scientists in January, "urged science and technology workers to help businesses and rural areas to speed up development and become productive. ***They should help improve management, develop new products and technologies, and actively involve themselves in economic development***."

A different attitude to science in the U.S.

So while the Chinese leadership is clearly behind science and its application to the economy, and while China has a ministry of science and technology, in recent years the U.S. Executive Branch moved the science advisor out from the White House. Our science investment culture and the community eschew commercialization, and selection or direction of science to economic ends is resisted by some policymakers who decry "Industrial policy." Our hope is that a technology push will lead to favorable economic outcomes as indeed it did in a different era and global environment. To me, the advanced technology trade balance (Figures 3.a and 3.b), should be evidence that the old model no longer works. I find the data more disturbing if I use a $200k figure per FTE to translate the 2008 deficit in to 277,500 high technology jobs (–with of course the $200k spent in the local community and on taxes.)

When I became CEO of Cleveland Crystals, a company with roots in materials for sonar in the 1940s (materials that became very useful for laser applications), I was told that experience taught that any new crystal product took ten years (and several million dollars) to develop for the market. Though this might be an extreme example, most significant new optoelectronic products (as distinct from incrementally improved products) do indeed take some years before payback. Crossing what Dr. Charles Wessner (Director, Technology, Innovation, and Entrepreneurship, U.S. National Academies) calls the idea to market "valley of death" is costly. Indeed, the route to product (the innovation process) is not the simple linear concept of idea to sales revenue, but much more complex and certainly not implementable to order. Though things may change, the recent expectations for short term financial return for U.S. corporations is incompatible with patient product R&D. When a CEO cuts R&D, the stock price rises and management is rewarded. That is not the case in Asia. In China it seems the financial structure and investments for technology are very focused and patient, not at the whim of meeting quarterly targets. Likewise, careers in S&T are more certain, more prestigious and valued.

Optical materials are an area where the U.S. has lost position, and China has taken leadership. China is the preferred source of some optical crystals used with lasers, a somewhat unusual area where Chinese companies have intellectual property rights in the US.

In 2008 I spoke with then SPIE member James Fergason, a liquid crystal pioneer, and the winner of both the 2006 Lemelson-MIT Prize, and the 1998 Ron Brown Technology Award from the U.S. Department of Commerce. (Sadly, Dr. Fergason died last December.) He received more than 130 U.S. and 500 foreign patents during his wonderfully creative career. Our conversation centered on why almost all the jobs related to liquid crystal display (LCD) technology were in Asia, though most of the invention was in the U.S. He pointed out that the facile response, lower labor costs, was not correct, as the labor content of the typical LCD was tiny. His view was that it was the result of major U.S. corporations' unwillingness to invest substantially and patiently. He also commented on the lack of visionary leadership in U.S. blue chip companies, and in the particular case of LCDs, attempts to protect older display technology (at that time owned by then substantial U.S. suppliers to the consumer electronics markets).

R&D in China.

Figures 4.a and 4.b show the trends in R&D spending in the U.S., the EU, China, and Japan. They are shown on both a market exchange rate (MER), and at purchasing power parity (PPP). Some argue that PPP gives the true measure of R&D activity, and if so, then China recently passed Japan to become the second largest funder of R&D in the national stakes. The U.S. and the EU conglomerate still outspend China, but the rate of increase should be noted. Chinese R&D spending is estimated at 1.6% of its GDP, with targets of 2% by 2010 and 2.5% by 2020. The EU's difficulty in having industry invest more so that it can reach its "Lisbon target" of 3% is in at least in a small way due to the preference of industry to invest in R&D in China.

The nature of R&D expenditure in China differs from that of the U.S. in that there seems little spent in basic science, and less on the life sciences. Applications and engineering are favored.

I have visited many optoelectronic laboratories including several of the key State laboratories in China, and can qualitatively compare them with laboratories in the U.S and elsewhere. A small number of the premier universities in China have facilities and equipment on par with the best university laboratories in the U.S. Outside the top tier, the equipment for experiments is older and more of it "home built." Students seem well equipped with up-to-date computers and it is not usual to see rows of students reading sophisticated documents in English on the screen and yet be unable to understand spoken English. Students have fewer options for study in China but my sense is that they pursue S&T with fervor, and not because that is all there is. Faculty at some universities in Beijing and Shanghai have mentioned that with affluence they are seeing less top flight local students, but there is a vast pool of talented students from the countryside. (Growing affluence is also driving labor intensive optics companies further from Beijing and Shanghai.)

Scientific Publications

Associations like SPIE see review, publication and archiving of research papers as part of our mission. The submission of research papers from China provides some measure of the open research activity. The number of papers from China has been growing so quickly that it threatens to overwhelm the capacity of the associations. Not all submitted papers are deemed suitable for publishing, and the ratio of submitted to published papers is lower for Chinese submissions than average, but it is trending upwards (Figures 5.a, 5.b, 5.c, and 6, from the American Institute of Physics (AIP) and SPIE's flagship journal, the Journal of Optical Engineering). Bear in mind that these are papers published in English. The lower quality and significant plagiarism problems are in part consequences of the extraordinarily rapid expansion of Chinese research and the openly stated policy of quantity first, quality second.

Much scientific publishing has become electronic; SPIE has a Digital Library of close to 300,000 scientific publications, all reports after 1990, and most classifiable as optoelectronic or nanotechnology. Downloads of scientific papers provide another measure of research activity. China is second only to the

U.S. in downloading from this library. (This SPIE body of work is the most highly cited source for patents at the USPTO in optoelectronic related fields.)

Intellectual Property in China

Although China has had extensive research programs and manufacturing operations in optoelectronics for a number of years, particularly in communications, there are as yet relatively few Chinese origin patents granted by the USPTO or EPO. Patent numbers are growing more rapidly at the Chinese patent office and the World Intellectual Property Organization (WIPO). Since neither of these bodies access SPIE's prior art, the patent scrutiny in optoelectronics is suspect.

Fit, form and finish copies of optoelectronic communications devices are entering supply chains in China and displacing legitimate company product (Figure 7). Anecdotes of companies being called for service under warranty only to find the product was not actually theirs are increasing, but there is no good data on how pervasive this problem may be.

Manufacturing of optoelectronics in China

China is the manufacturing or assembly base for many of the world's leading optoelectronic manufacturing companies. Shenzhen and Wuhan are optoelectronic manufacturing hubs for communications products, and more recently light emitting diodes (LEDs). As for most high tech goods, China is chosen for assembly and packaging rather than for fabrication of key components. However, Chinese optoelectronic companies are springing up and quickly becoming competitive in world markets.

Huawei is an indigenous company in the communication component and system sector, including optical networks. It had $12.6 billion in revenue in 2007, and has become a force in the world market. Han's Laser has grown quickly to become a top five "laser company" (with $100 million in annual revenue). Chinese companies and foreign owned plants producing solar panels (photovoltaics PV) are growing rapidly. (The Chinese government has identified this industry as one of the nation's targets.) China's PV production has been growing at 25.5% per year since 2001, and in 2008 China seemed to be the world's largest producer of PV. The U.S., home to much of the original R&D for PV, had about 1/5 of China's PV production output in 2007. Suntech is the largest of more than 50 PV companies in China, and is ranked as the third largest producer in the world.

Recommendations

The recently enacted American Recovery and Reinvestment Act of 2009 (ARRA) as well as the FY 2009 Omnibus Budget legislation include boosts for R&D in the U.S. This is a necessary and important step. However, in itself it is unlikely to bring us back to a healthy U.S. high technology economy. Undirected scientific research is deserving and important for the future. What we need to do is examine whether the conditions where R&D gave us economic leadership still exist, and if as I believe, we find they do not, then we must move aggressively to establish a new innovation infrastructure that will make us competitive again. We no longer have research powerhouses like Bell Labs that straddle academia and industry, but we do have small innovative companies, and support for science parks will strengthen that sector. Taiwan has brought this to a new level; way beyond what we envisaged for science parks.

Many of our small companies scale up manufacturing in Asia, just as our admired larger innovators do. The value is added to the iPod and the iPhone in Asia, with components from around Asia and assembly in China, all far from Silicon Valley. We need investment in key manufacturing technologies of the future. The TIP program at NIST is a small step in the right direction, but its funding is totally inadequate.

The excellent SBIR program should be expanded and the evaluation process should place more emphasis on local job creation. Repeat applicants who can show a record of local job creation should be strongly favored. The part of the SBIR program that serves to support the DOD laboratories with their technology needs should be recognized as different and treated accordingly.

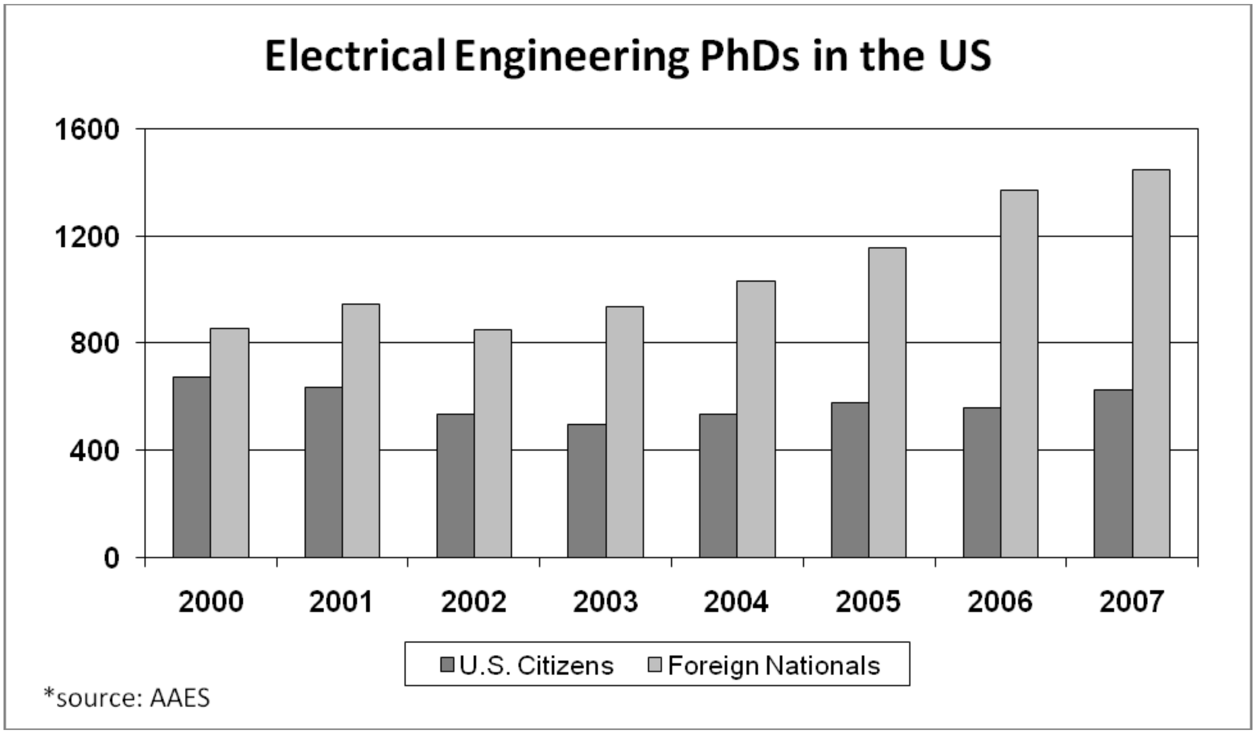
We need a comprehensive informed review of our fragmented national technology portfolio and ongoing active guidance. Much more emphasis on capital investment in manufacturing technologies and training of people will be vital. Yes, we need the science base, but we will not remain competitive if the $200 billion or so currently spent by industry annually in the U.S. follows manufacturing to offshore places, as it inevitably will with the explosion in S&T capability in populous China.

We may continue to be world leaders in the science of LEDs or the semiconductor lasers that power the internet, but the location of the semiconductor foundries and the know-how to manufacture in volume suggest that the manufacturing jobs will be in Asia, many of these in China. We need to select key manufacturing technologies and do what is needed to have world leading "plants" in the U.S. The decades of work in the DOE laboratories, notably NREL, should lead to solar energy manufacturing here, not to installation and maintenance of imported panels and outflow of incentive dollars to support jobs elsewhere.

Science, Technology, Engineering & Mathematics (STEM) education for our workforce will be vital, and in this we are no longer competitive. Excellent initiatives have been proposed in the "Rising Against the Gathering Storm" report. We must also devise opportunities and strong incentives for career retraining; this is crucial for lifetime technology careers. Again these educational thrusts must be part of an overall plan for rebuilding our technology economy. We should not expect young people to pursue careers that will not exist in this nation.

I have little doubt that my recommendations do not meet free market criteria, nor will they be to the liking of those opposed to government involvement. My response is that I love the principles of the free market, but when I look at our trade deficit (especially the trend in high technology trade), I can't help but think it is due in part to other governments attending to the economic wellbeing of their people. I suspect they are the strongest proponents of keeping the U.S. market "free."

Figure 1:



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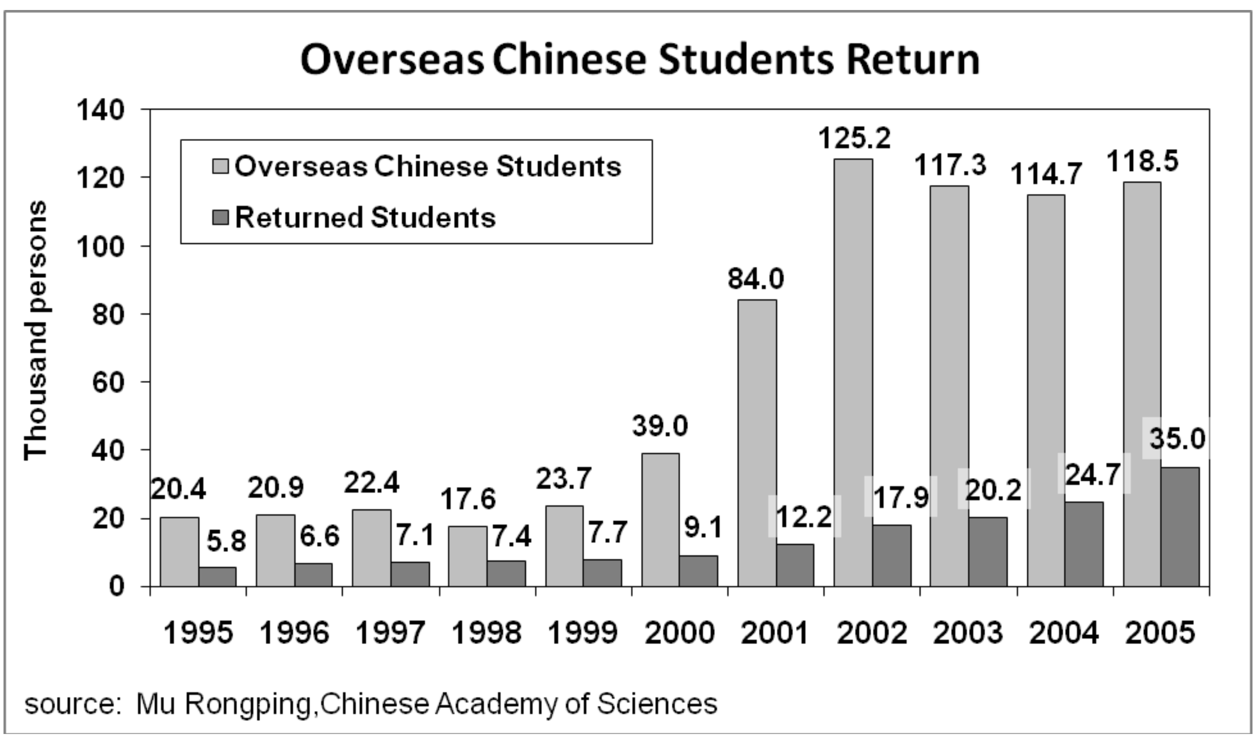

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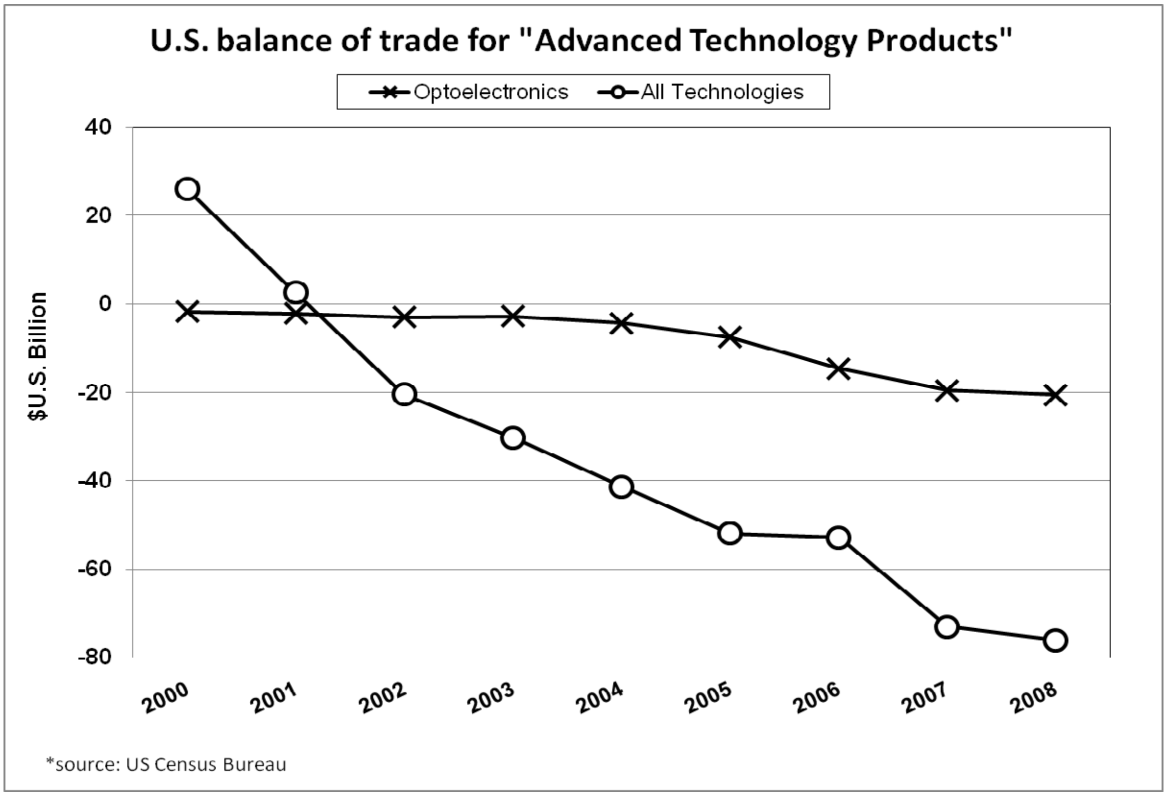

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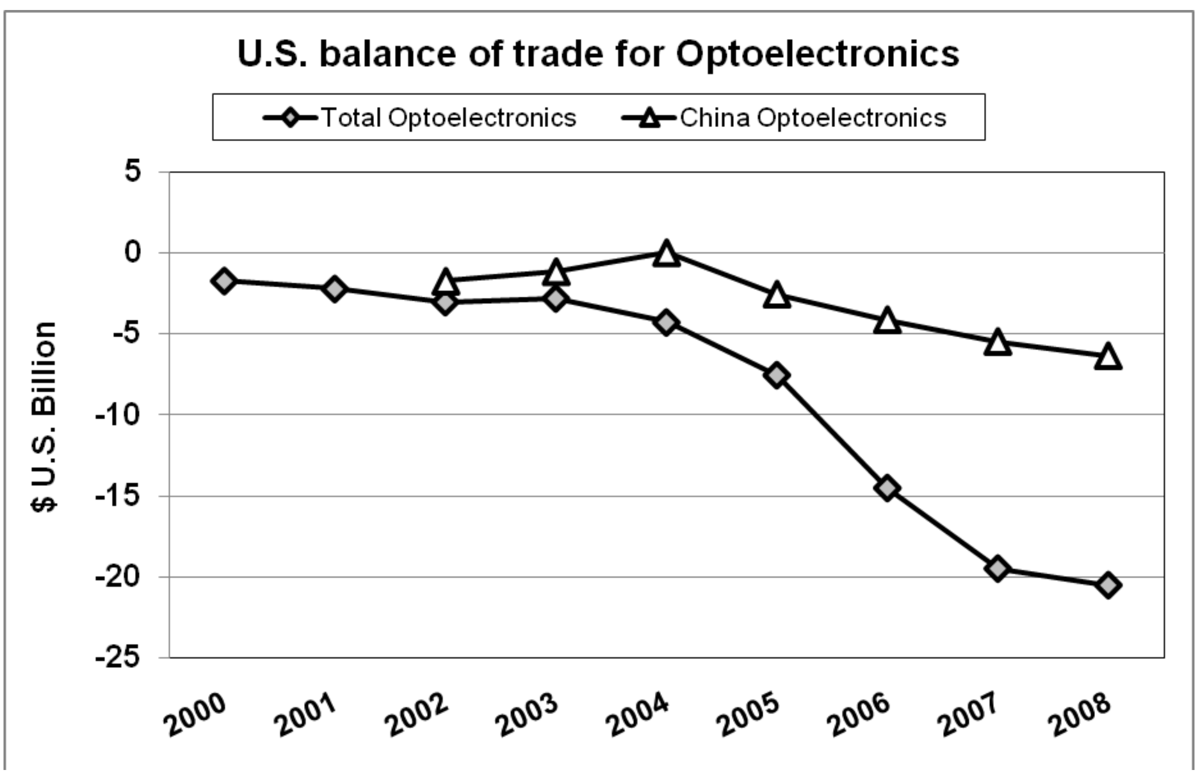

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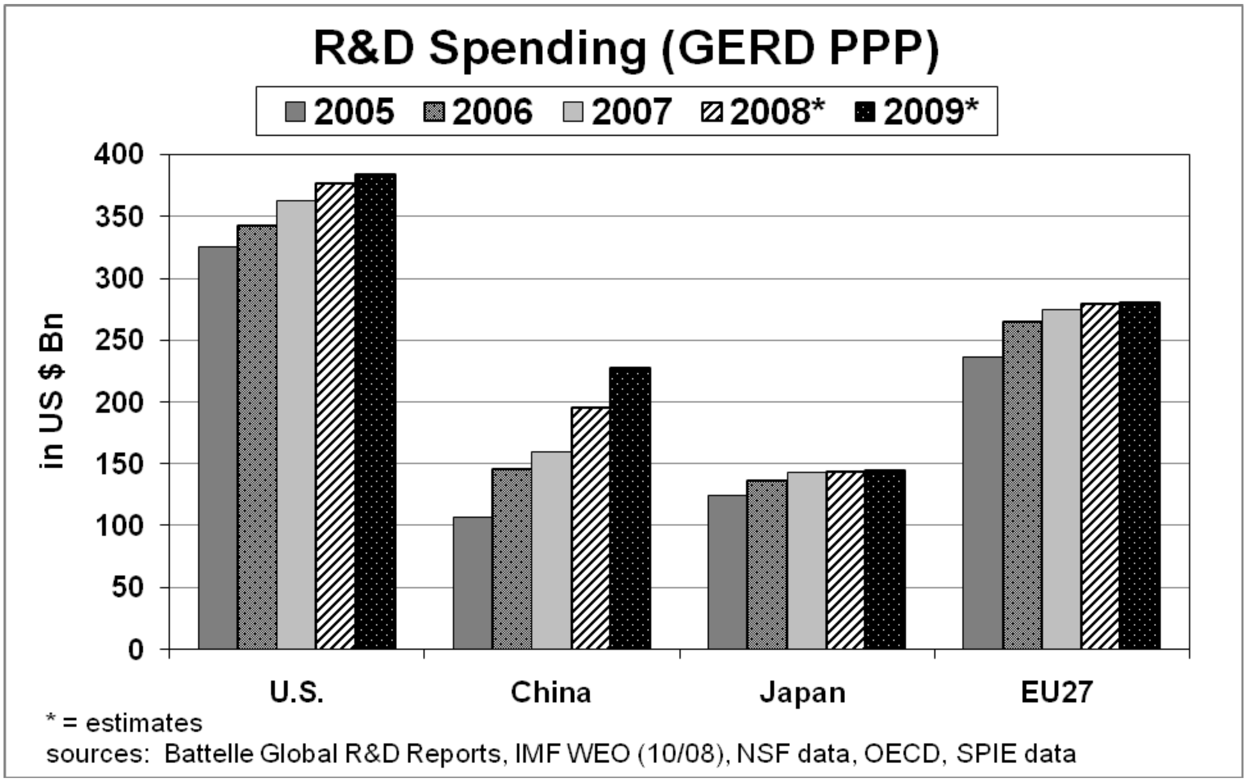

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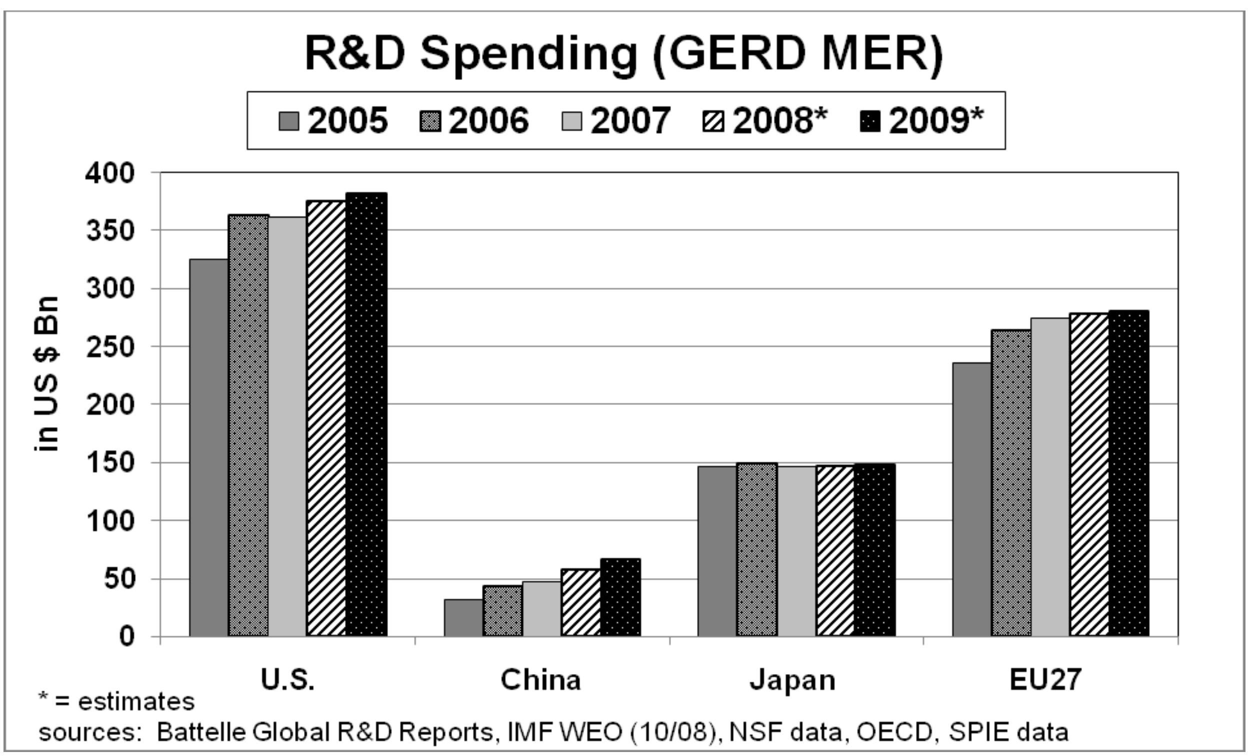

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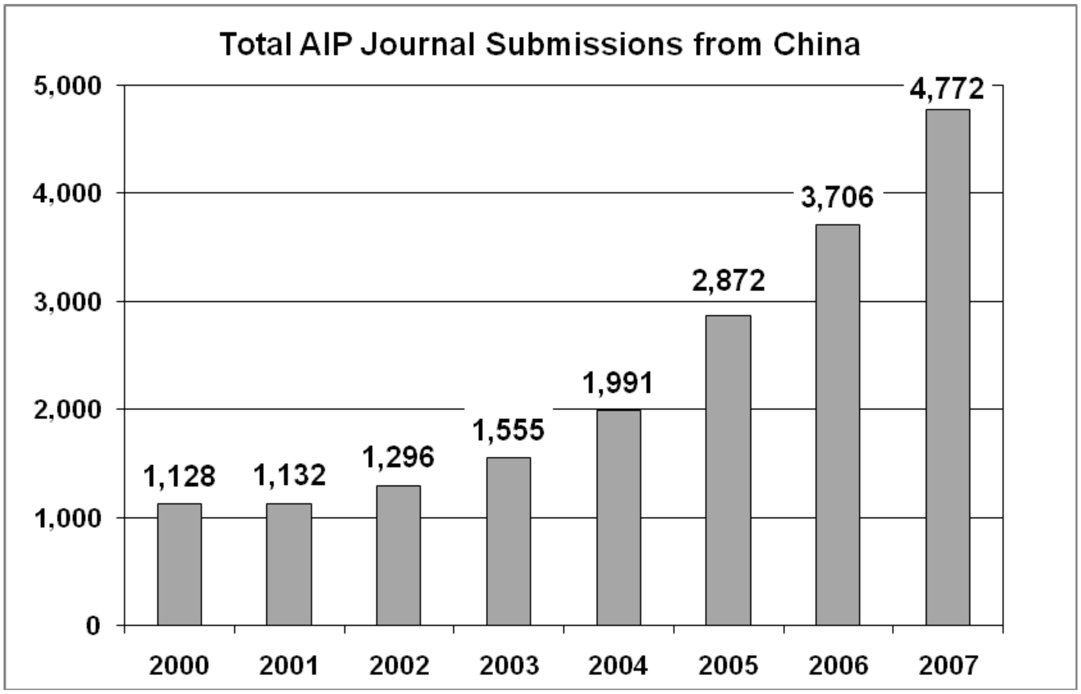

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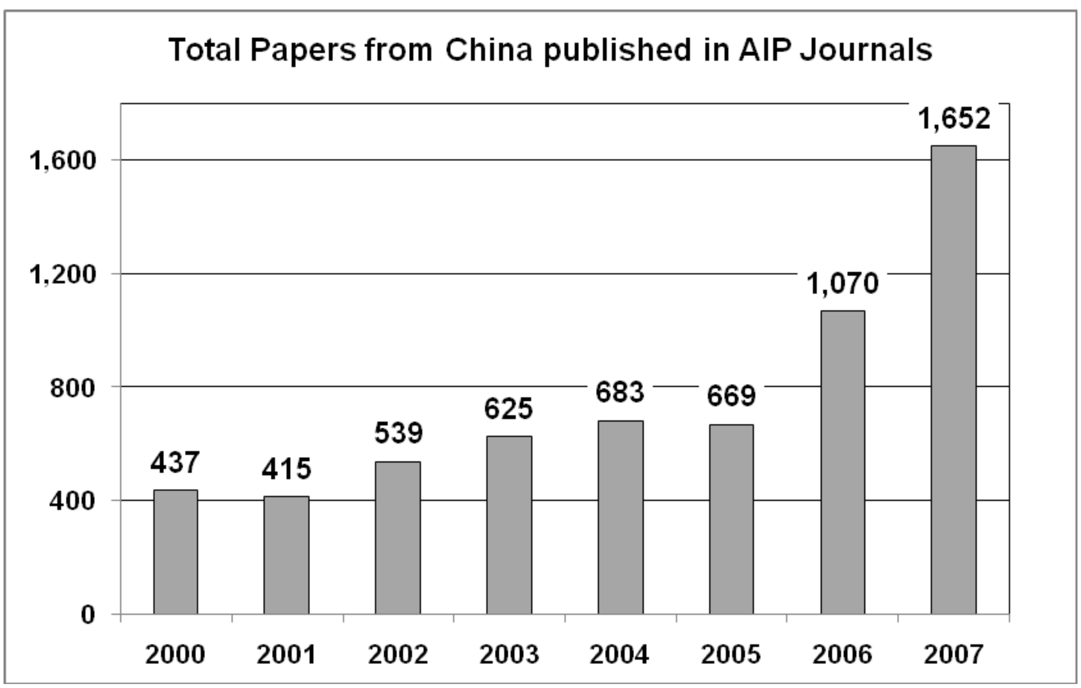

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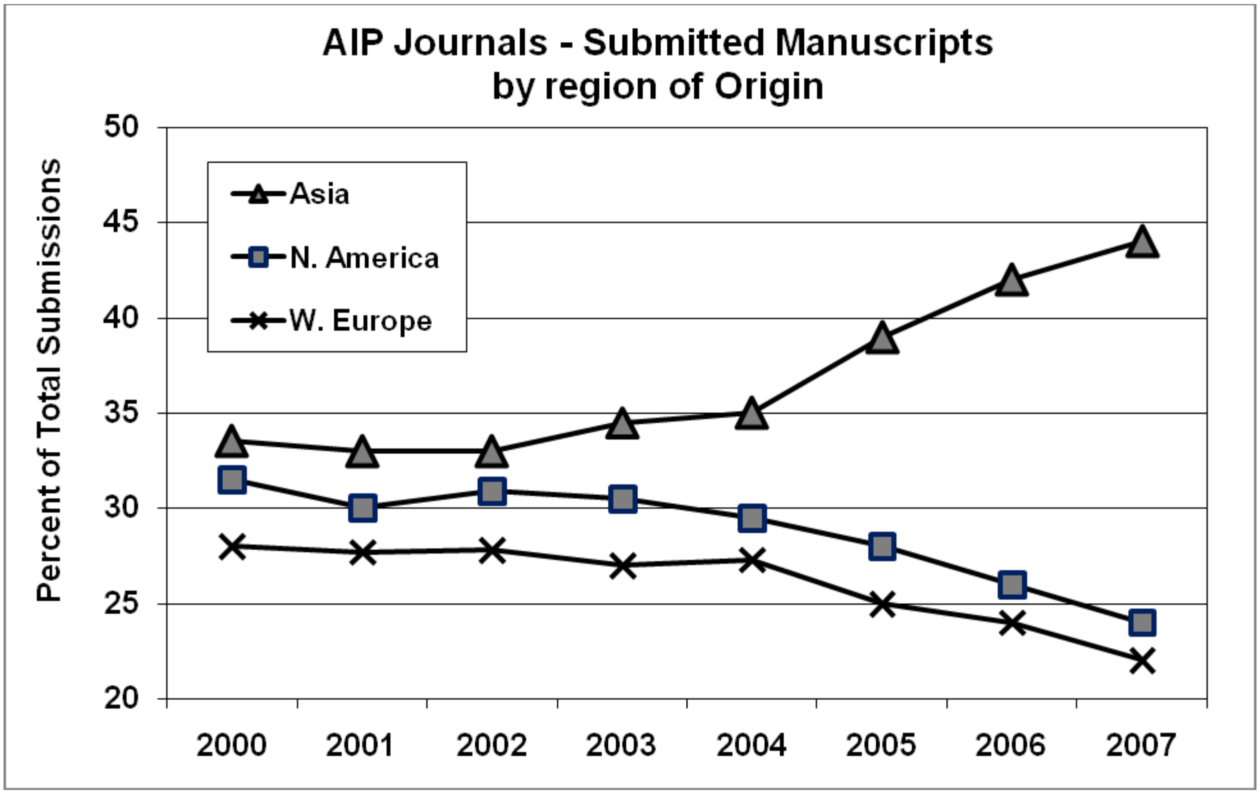

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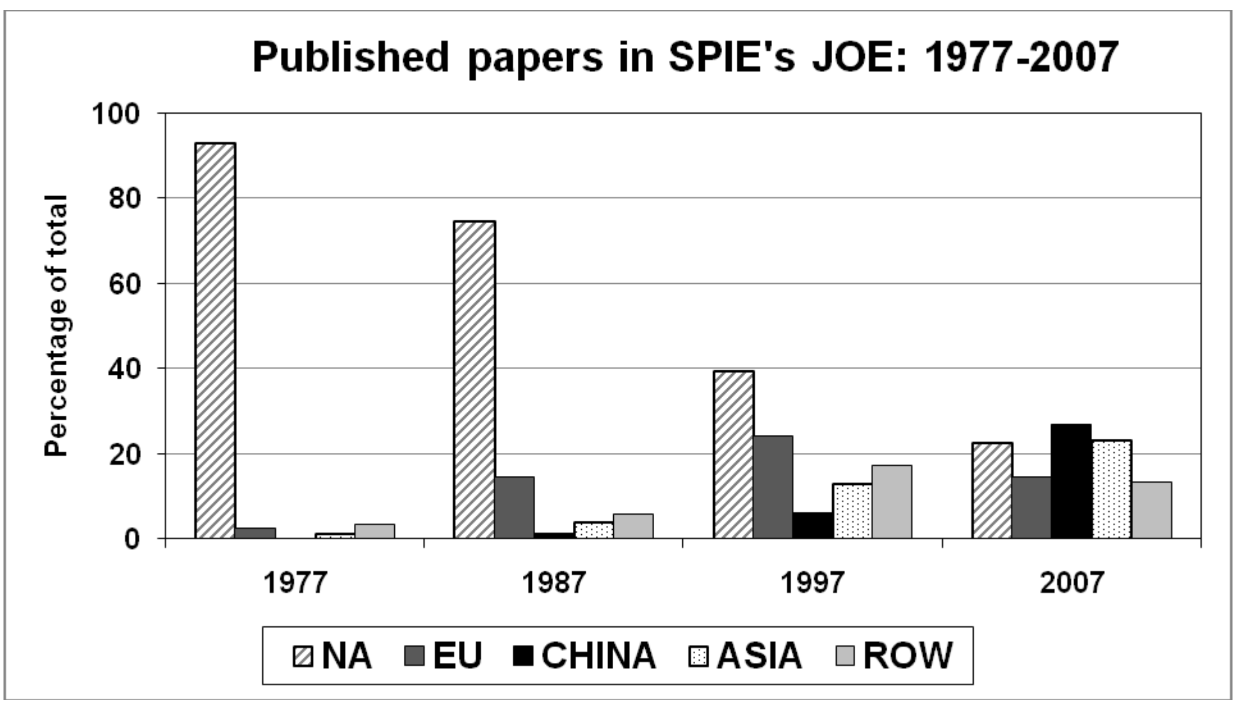

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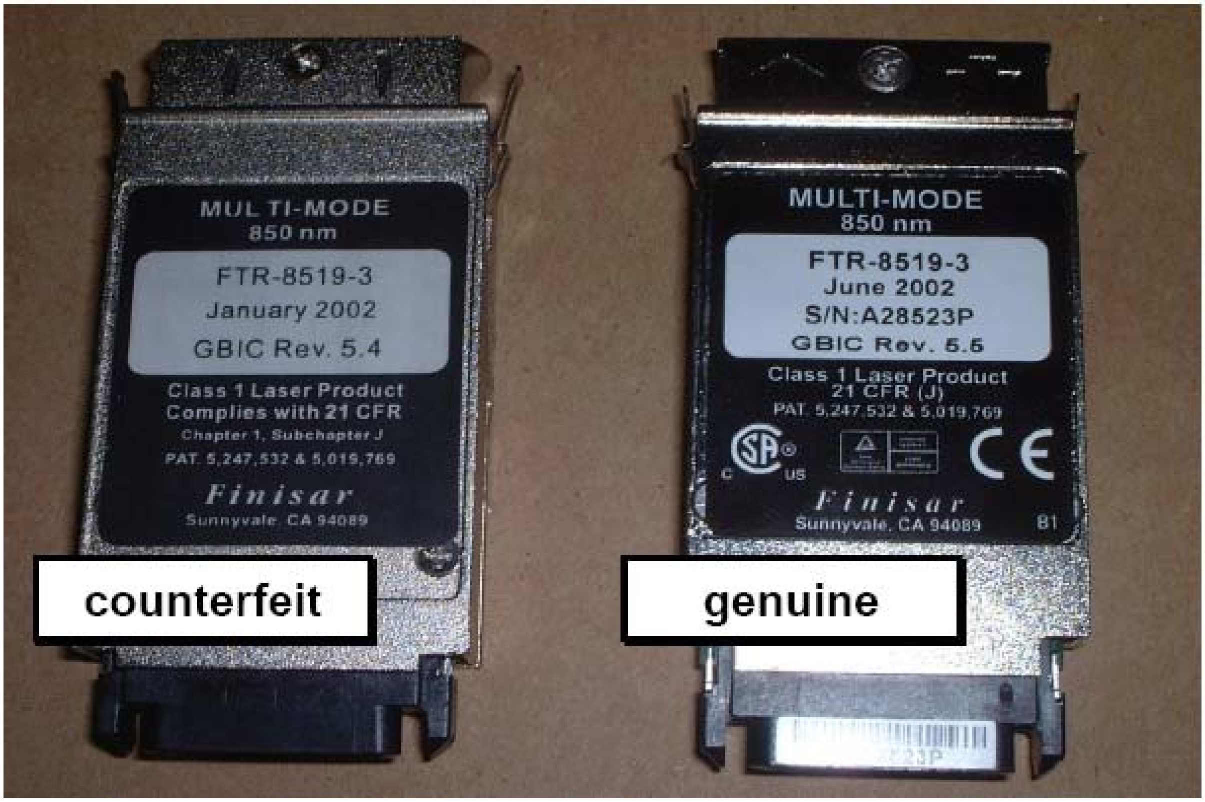
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January 2002
GBIC Rev. 5.4
Class 1 Laser Product
Complies with 21 CFR
Chapter 1, Subchapter J
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