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National Laser Research Progress in Context of International Developments

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Abstract: This study presents an up to date progress of the national and international laser research and developments. The number of scientific publications and accepted patents are considered as a figure of merit and based on these numbers the growth pace for the period of 1990-2003 is investigated. The share of top nations in scientific publications and in particular laser publications in term of their Gross Domestic Product (GDP) is presented. Four countries including the USA, Japan, Germany and China have a laser publication contribution of 58.9% while the rest of the world including (189) countries contribute 41.1%. However, for the case of accepted patents, which are the more important factor, these four countries hold a share of 90.1% while the remaining nations have a small share of 9.9%. The USA leads all the nations in the number of scientific publications, citations and laser publications, however, in terms of accepted laser patents Japan shows a big lead and has the highest patent/paper ratio (0.46). For Iran the total publication is 231 items (0.06% share) for the period of 1990-2003.

Key words: Laser research, paper, scientific publications, developments

INTRODUCTION

Recent developments in laser research programs are described in terms of resulted publications. However, there may be another figure of merit for such investigation (experts involved, capital involved), but the most accurate one seems to be the evaluation by the number of published papers and filed patents. Using this figure of merits the state of the art in this field is setup and the most recent developments are presented in terms of resulting publications. By using the Science Finder Scholar search engine the numbers of scientific laser publications cited in data bases are surveyed. However, it must be pointed out that these numbers are not the complete list of the publications in this field because some of the published documents are not included in this data base. Also, the search results are depending to the search term and some errors must be considered in the final analysis. It is however a good and reliable source that illustrates the historical growth and the purpose of this study.

The introduction of laser and related devices have revolutionized the high technology and made a great deal of contribution to both the basic and applied research in different areas. Although the present laser systems have not fulfilled all the preliminary expectations, but important advancements have been made by the advent of sophisticated laser systems in optical communications (Senior, 1992), medicine (Stock and Hibst, 2008), industry (Molpeceres *et al*., 2007) and other fields (Muncheryan, 1991; Gondal *et al*., 2002). For different countries it is important to evaluate the impact of their research investments in terms of the end results. Such information can be used for the future planning and budget contribution to the related field.

Even though, such investigation is trivial for more advanced and developed countries, but to my knowledge, such a study to the given extent has not been conducted for the case of Iran. This makes the reported results very honorable and valuable for decision-making and goal setting. The aims of this study are threefold. First, describes the state of the art of laser systems by looking at the published materials. Second, goal is to investigate the impact of our domestic laser research in terms of publications and its contribution to the scientific world. By comparing our domestic contribution to that of international community one can learn some lessons for the success of future domestic research.

MATERIALS AND METHODS

The aim here is the understanding of degree of the laser reach success in different countries in terms of resulting publications. The early search of information was conducted in 2004 in USA and it was completed later for this paper. The comparison of the results clearly shows the possible potentials and weaknesses, which might be looked up to in future for a faster pace of laser developments. First let me consider laser developments in different countries. The early developments of the laser research started from the USA and Soviet Union in 1958. By 1960 about five different types of lasers were

introduced to the scientific community and the acronym lasers was accepted as a global name for this quantum generator machine. Since then scientists from some other countries contributed to the development of this revolutionary field. During the past fourteen years from 1990-2003 considerable efforts have been made in the development of new laser systems and related equipments both in terms of science advancements, technological break troughs and also field applications. From the explored search under the topic lasers the total number of publications for the period of 1990-2003 is 351824 publications. For the same period the number of the accepted patents is 48448 items.

In the first study, the contributions of different countries are shown in terms of published papers and filed patents in Table 1. A glance through such publications shows that most of the contributions are coming from the research institutes in the USA, Europe, Japan, China, Korea and some from other countries in collaboration with the mentioned ones. The USA has the lead (24.1%), Japan in second (20.5%), Germany (8.6%), China 5.6%), respectively and other European countries (for example UK, 4.03%) and other countries are shown as a group score of (41.1%). A careful look at the filing patents reveals that like journal articles, most of the contributions are coming from the research institutes in the USA, Europe, Japan, China, Korea and some from other countries at a lower scale. However, as shown in Table 1 in filed patents Japan shows a lead with an amazing score of (69.7%), the USA in second (14.9%) and after that Germany (5.4%), respectively and the other countries (9.9%). The share of Europe is the main contribution of the group category and is estimated to be about 9%. For example, for UK is about 1.07% for published patents in laser area.

To see the international annual growth of laser research, in Table 2 the number of publications including filing patents is shown for the 1990-2003 period. The growth is noticed in this filed as in year 1990 there is only 17186 published papers while in 2003 reaches to about 33214 papers, which shows an overall growth of 93.26% and average annual growth of about 6.66% for this period. In Table 2, the number of the patents in the laser area is also displayed for the same period of 1990-2003. Table 2 shows also an increasing growth in the number of patents in this field for the same period of time while it increases from 1877 patents in 1990 to a high number of 7269 patents in 2003 (average annual increase of 20.5%). A sharp increase in the filing patents are noticed since year 2000 (5020) as can be shown in Table 2.

In another study, the written language of publications is investigated and the results are shown in Table 3. The search engine provides opportunity to check

Table 1: Percentage of laser publications and patents in different countries. Total number of publications from 1990 to 2003 is 351824 papers and 48448 patents

Country	Paper (%)	Patent (%)	Pat./Pap.
USA	**84927 (24.1)**	7243 (14.95)	0.0852
Japan	72139 (20.5)	**33808 (69.78)**	**0.4686**
Germany	30590 (8.7)	2626 (5.42)	0.0858
China	19849 (5.64)	376 (0.77)	0.0189
Russia	15626 (4.41)	422 (0.87)	0.0270
UK	14211 (4.03)	520 (1.07)	0.0365
Italy	7278 (2.06)	104 (0.21)	0.0142
S. Korea	4747 (1.35)	666 (1.37)	0.1402
India	3736 (1.06)	10 (0.002)	0.0026
Spain	3299 (0.93)	29 (0.05)	0.0087
Israel	2711 (0.77)	111 (0.23)	0.0409
France	2149 (0.61)	27 (0.05)	0.0125
Brazil	1452 (0.41)	10 (0.002)	0.0068
Finland	1327 (0.37)	29 (0.05)	0.0218
Greece	1039 (0.3)	3 (0.006)	0.0028
Swiss	761 (0.21)	0 (0.0)	0.0000
Egypt	316 (0.08)	0 (0.0)	0.0000
Rep. Ireland	269 (0.07)	4 (0.008)	0.0148
Turkey	260 (0.07)	0 (0.0)	0.0000
Iran	231 (0.06)	0 (0.0)	0.0000
Pakistan	26 (0.007)	0 (0.0)	0.0000

Table 2: Annual growth of global laser publications and patents during 1990-2003

Years	No. of papers	No. of patents
1990	17186	1877
1991	18657	1919
1992	19057	2227
1993	20011	1988
1994	20463	1940
1995	21297	1999
1996	25875	2517
1997	25521	2377
1998	26697	2433
1999	26917	3086
2000	30004	5020
2001	32472	6443
2002	34554	7354
2003	33214	7259

Table 3: Different languages for publications

Language	Papers	Patents
English	275859	12667
	78.37%	26.14%
Japanese	39231	31162
	11.14%	**64.31%**
Russian	12872	680
	3.65%	0.14%
Chinese	10615	421
	3.01%	0.87%
German	7368	2683
	2.09%	5.54%
French	2440	492
	0.69%	1.01%
Polish	575	26
	0.16%	0.05%
Spanish	456	23
	0.13%	0.04%
Italian	348	12
	0.09%	0.02%
Others	2207	287
	0.67%	0.60%

for the publications in different languages. The result for the number of published papers in English is (275879), German (7368), Japanese (39231), Chinese (10615), French (2440), Italian (348), polish (575), Russian (12872) and in Spanish (456) papers. Publications in English are the highest (275879) while among listed languages the publication in Italian is the lowest (348) for the searched period of 1990-2003. It must be pointed out that some of the publication are translated and probably published in two or more languages. For example, some Russian articles are translated and published in English as well. Adding up the number of publications in different languages together and comparing with the total gives the number of publication written in other languages to be (2207). This study shows that English is accepted as an international language (78.37%) for the most peer refereed articles. However, on the filed patents the number of the published patents in Japanese is about 64% while in English is 26%, which shows the degree of laser progress in Japan.

Now, consider the global developments in terms of different disciplines. In this study the areas for the laser research and their importance are investigated. Table 4 shows the results listed for the period of 1990-2003. The major areas include optics, chemistry, biology, photonics, material science and industrial uses for research and application purposes. The search is performed under the topic term such as laser in optics for both papers and patents. As can be seen from Table 4, there have been a lot of studies in the fields of optics and laser chemistry. Laser system has provided a new opportunity for the optical communication system in which a large volume of data can be transmitted through the optical fiber cables. Semiconductor lasers and optical fiber amplifiers play the important roles in this respect. The interesting point in Table 4, is the number of patents for lasers in optics that shows the significance of this field and more attention should be paid to this field in future. The patent/paper ratio in this category is about 0.17 and most of the patents are as a result of accomplishments in Japan and in the USA.

Published papers and patents for different laser processes are also investigated. Laser spectroscopy is the leading process and laser microscopy, material processing, laser fusion, laser applications and laser diagnostics are noted, respectively. In the category of laser spectroscopy the number of publications is 42463 while the number of filed patents is 1571. The least publication in described categories belongs to laser diagnostics with publication number of 3082 and only 88 patents.

Table 4: Different areas for using lasers

Laser research scope	Paper No.	Patent No.
Optics	95715	16495
Chemistry	37865	2792
Biology	16958	1321
Photonics	17297	503
Industry	4242	155
Communication	2427	944
Material science	295	4
Life science	139	4
Surface science	113	1
Aerospace	83	0

In the material processing by laser systems the major applications are welding, drilling, hardening and laser engraving. From a total of 5954 publications for this area welding research has devoted 4993 papers with the number of 1288 patents. Laser hardening is in the second place with a number of 1553 published papers and 305 patents. Laser drilling is another potential application for industrial laser systems, which devoted a number of 1237 papers and 381 patents. Finally, in this category, laser engraving research has resulted 165 papers and 86 patents.

To see how experimental work in laser area competes with the theory, in the next study the documents are searched under the term experimental laser research resulting a number of 24552 papers while for the theoretical one shows a number of 6030. This comparison shows the importance of the experimental works, which leads to advancing laser technology. Some studies are involved both the experimental and theoretical works, which has resulted a number of 4176 papers. The search under the topic of application of lasers results a number of 26966 papers at the date of search for the period of 1990-2003.

Finally, let us consider the developments in terms of different laser types. Historically, the first build laser was the ruby laser as result of Maiman's effort (Maiman, 1961). The He-Ne (Javan *et al*., 1960) and other gas lasers were developed shortly after and now many type of lasers are commercially available. Looking at the past trends indicates that there are more tendencies towards, smaller and more efficient semiconductor and all solid-state lasers. To see the importance of each category, the second search is accomplished under the term of different laser types such as CO_2 laser. Similarly the filing patents in each field of research are also studied. These include the number of publications for different laser types such as Semiconductor laser, Infrared, Excimer, Ion, Chemical, Nd: YAG, X-ray, CO_2 and Nitrogen laser.

As far as publication of the paper concerns the semiconductor laser devotes the most number of

publications (32750 papers and 14419 patents). The next important type is infrared lasers (20812 papers and 2257 patents). For nitrogen laser the number of publication is around 5213 published papers and 524 filed patents. For the He-Ne laser, the published papers is 4540 while the number of the patents is 199 for this type. Also, for the metal vapor lasers the number of publication is 1374 and the number of accepted patents is 291 items. For the ruby laser the number of publications is 907 papers and 20 patents. In the area of semiconductor lasers a great deal of attention has been paid to the quantum well and quantum dot lasers (Cao *et al*., 2000). As a result of different studies the number of publication for the quantum well laser is about 8673 with the number of 1637 patents. This signifies the importance of the quantum well lasers.

The laser systems in general can be classified as pulsed and CW lasers. As can be seen, the major contribution is related to the pulsed lasers. The number of publication for pulsed lasers is 58299 papers and 3035 patents while for the CW laser publication number is 4408 and 64 patents. For the Q-switched laser the number of publications and cited patents are investigated. A great deal of research has be devoted to the development of the Q-switching and mode locking in order to improve the pulse quality for high resolution and femtosecond studies. The credit in this respect goes to the high power pulsed CO_2 and Nd:YAG lasers.

There has been great interest in the solid state physics for the development of new soliton and polariton lasers (Kavokin *et al*., 2003). To see the impact of such new studies, in a search under the term soliton and polariton lasers have been investigated. For the period of 1990-2003, the number of publication for soliton lasers is 719 including 13 patents. For the polariton lasers, the total number of publication is about 201 with only one patent for this period of 1990-2003. However, the work in this area continues and there is a promise for the new lasers in future. Such achievements introduces laser in the new frequency range with new potentials. Higher power and efficiency have been the ultimate goal for the most applications. From the early days of making drill in the laser blade as a test of laser power and yet the main concern has been to generate higher powers. Under specific topic of high power lasers the resulting publication is about 10672 and accordingly the number of patents is higher for the special powered systems with a number of around 906 patents. However, quantity and quality are two important parameters in the effectiveness of the laser systems. All the time these two go hand in hand and always increasing the laser beam quality results a decrease in its output power.

Another problem is that up to now most of the high power lasers operate in the Near IR or far IR and there are Excimer lasers that have considerable power in the UV region. So there still a gap in the middle of the spectrum and that motivated goal for introducing laser systems for UV/VIS region of the electromagnetic spectrum. As described, for the x-ray a number of 9267 papers along with 389 patents have been cited. Under the term of low wavelength lasers there 918 published papers including 176 patents. For the topic of nuclear pumped lasers the resulting publications is about 364 including 3 patents for the period of 1990-2003.

Safe operation of the laser systems has been described in different regulation documents, laser safety books and technical application notes. The safety operations have been documented for four different classes of lasers mainly considering the laser output power ranges. For this subject, a search is performed under the term laser safety and the result of that investigation is the resulting 2402 papers and 113 patents for such a period of time. In the future, safety problem should be considered especially for the up coming high power giant oscillator-amplifier chain systems.

LASER DEVELOPMENTS IN IRAN

Let me consider the domestic growth of laser publications. Using the search program under term lasers a total number of 231 publications including articles in journal and conference proceedings in different languages are resulted for such a period of 1990-2003. The average number of publications per year for this period is about 16.5 papers. The progress of such publications is shown in Table 5. As can bee seen in Table 5, the number of publications in 1990 is only 8 papers while, it reaches to 41 in year 2003. That is a considerable progress of about 29.46 % and further increase is expected in future. For this period of 14 years, the annual growth is noticed, which is indicative of the increasing interests in this subject.

Table 5: Annual growth of laser publications in Iran during 1990-2003

Year	No. of papers
1990	8
1991	2
1992	1
1993	13
1994	8
1995	11
1996	14
1997	29
1998	13
1999	15
2000	20
2001	23
2002	33
2003	41

Table 6: Types of listed laser publications in Iran

Types	No. of publications
Journal	216
Journal article	21
Conference paper	12
General review	10
Case study	4
Preprint	2
Book	1

Table 7: Native publications in different disciplines

Field	No. of papers
Optical, electron and mass spectroscopy	102
Pharmaceuticals	14
Electrical phenomena	10
Plastics manufacture and processing	10
Synthetic elastomers and natural rubber	10
Physical properties of synthetic high polymers	9
Nuclear technology	7
Ferrous metals and alloys	5
Other related topics	64

The distribution of published papers is presented in Table 6. The search engine is so arranged that can classify the publications as journals, journal articles, general review, case reports and books. For example, such publications as listed by the search engine include papers in journals (216) journal articles (21) conference papers (12), case reports (4) and book (1) as shown in Table 6.

Now, consider the laser developments for different areas in terms of resulting publications. The major areas for such research are shown in Table 7. Disciplines given include optical, electron and mass spectroscopy that results the most publications (102) while pharmaceuticals (14), electric phenomena (10), plastic manufacturing and processing (10), synthesis elastomers and natural rubber (10), physical properties of synthetic high polymers (9), nuclear technology (7), materials and alloys (5) and other areas of the laser (33) are in turn the most important studied issues. The laser research in Iran is concentrated in the area of design and construction of different laser systems (Golnabi, 1993; Tajalli *et al*., 2002; Jelvani *et al*., 2003; Farahbod *et al*., 1999; Bahrampour and Ganjovi, 2003) and related components, laser plasmas (Mahdieh and Hall, 2003; Maraghechi and Sepehri Javan, 2001; Golnabi, 2002), laser polymer interaction (Dadsetan *et al*., 1999), related optical designs (Golnabi, 2004; Shahshahani *et al*., 2002), detecting systems (Koohian *et al*., 2001), engineering applications (Tehrani *et al*., 2001) and medical applications (Mozdarani and Monfared, 2001). Some works have been done in the area of laser scanners (Golnabi, 2003) and laser based sensors for vision systems usable in manufacturing and automation applications (Golnabi, 2003). The aim of such research has been to develop and expand more industrial applications of lasers and laser-based systems.

The language of such publications is mostly English (192, 83.11%) and some in Persian (39, 16.89%). The percentage of papers published in English is 83.11% while

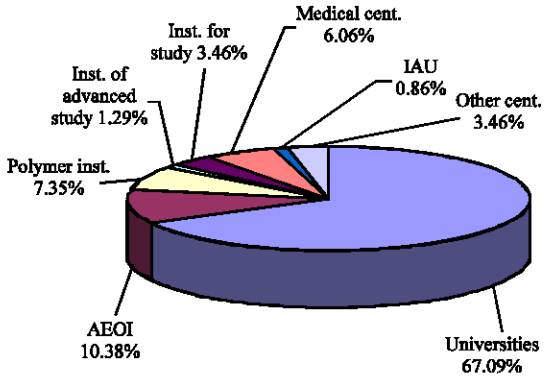

Fig. 1: Contribution of different institutes in Iranian laser publications. AEOI-Atomic Energy Organization of Iran, Iran Polymer Institute, Institute for Advanced Studies in Basic Science, Institute for Studies in Theoretical Physics and Mathematics, Medical Cent-Medical University and Centers, IAU-Islamic Azad University and other-other research institutes

as can be shown in Table 3 for the global publications is 78.37%. As can be seen there is a higher tendency in domestic laser research to publish in English rather than other languages. In Fig. 1 the contribution of different research institutes and universities in Iranian laser publications is shown. The percentage share of publications are as follows: Universities (67.09%), Atomic Energy Organization of Iran (10.38%), Iran Polymer Institute (7.35%), Medical University and Research Centers (6.06%), Institute for Studies in Theoretical Physics and Mathematics (3.46%), Institute for Advanced Studies in Basic Science (1.29%), Islamic Azad University (0.86%) and other research institutes (3.46%). As can be shown in Fig. 1, the main contribution in laser publications is coming from the universities. Among research institutes AEOI is leading and Iran Polymer Institute (7.35%) is in the second position.

In Table 8, the share of different universities in Iranian laser R and D are presented. The number of publications are Amir Kabir (29), Sharif University of Technology (20), Shiraz (16), Tabriz (16), Isfahan (13), Tarbit Modarres (12), Shahid Beheshti (7), University of Tehran (6), Teachers Training (6), Valie Asr (5), Emam Hossein (4), Kerman (4) and other universities (11) publications. Universities such as Amir Kabir and Sharif have the most contribution. It must be pointed out some of the listed places for the publications are common and there are joint collaborations mainly between the Amir Kabir and AEOI. Therefore, some of the papers are listed for both places and that makes the individual comparison difficult. Even though, the numbers for the comparative

Table 8: Share of different universities in Iranian laser R and D

Institute	No. of publications
Amirkabir	29
Sharif University of Technology	20
Shiraz	16
Tabriz	16
Isfahan,	13
Tarbit Modarres	12
Shahid Beheshti	7
University of Tehran	6
Teachers Training	6
Valie Asr	5
Emam Hossein	4
Kerman	4
Other Universities	11

publications are misleading for such institutes, however, gives an accurate comparison for the individual independent institutes.

As mentioned the total number of the laser publication is 231 at the search date and from these publications about 192 items are articles published in different international and national journals. From these numbers about 108 papers are listed by the ISI and the contributions of some of the journals are shown in Fig. 2. The number of ISI publications per year for this period is about 7.7 papers. The conference proceedings papers for both the international and national conferences are about 34 publications. The remaining 6 publications are case reports in the laser area. Considering the total of conference publications, about 22 of those are international (while SPIE is leading with a number of 20 contributions) and about 12 are national conferences. As can be shown in Fig. 2, most of the ISI listed papers are published in journals such as Physics of Plasmas (14, 12.9%) that shows the importance of laser research in that particular area. The second rank belongs to the papers published in Laser Physics (8, 7.4%) and Phys. Rev. E, which have a contribution of 8 papers. There are variety of other ISI journals with only one publication and a total number of 53 papers are published in such journals.

For developing countries such as Iran it is important to devote a proper fraction of the Gross Domestic Product (GDP) to each scientific field of research and on the other hand to set proper goal and level of expectation for the outcome of such research spending. On the other hand, to have a good figure for the turn over/capital cost ratio, which is an important factor for any investment, we need a good evaluation from our research program. As noted government-supported universities and research centers such as AEOI are the major institutes for laser research involvements and practically there is no competition and private laser research establishment. Almost all of the research projects in laser field are funded by the government in Iran and therefore, not many publications are listed under the name of the private sectors.

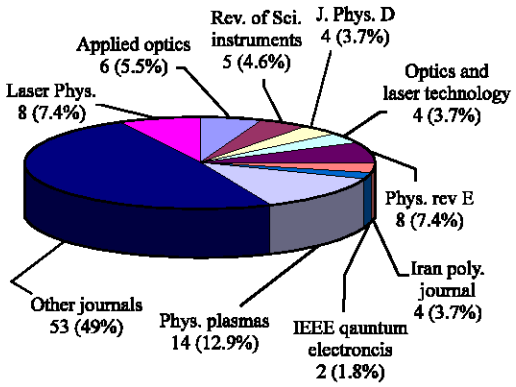

Fig. 2: Number and percentage of published papers in different ISI listed journals (108)

COMPARING DIFFERENT COUNTRIES

The scientific impact of nations in terms of publications and research spending is reported recently by King (2004). Information given in that reference for the number of publications and citations in general is used for comparison of the laser publication in different countries. In that article author has used information provided by Thompson ISI, the Organization for Economic Co-Operation and Development (OECD) and the World Bank.

For this purpose, a comparison of contributions are shown in Table 9. As mentioned in that report a figure of merit for such evaluation is the number of published papers and citations. Another important parameter in this respect is the number of filed patents, which leads to innovations and technological break troughs. The rank order for the publications and citations are presented in Table 1 of (King, 2004) for different nations. Such results are based on share of 1% of highly cited publications for the period of 1997-2001, which covers part of the period of interest for this study (1990-2003). In that report, the outputs have been compared relative to population and Gross Domestic Product (GDP). The number of citations per papers is another useful factor, which is given as Re-Based Impact factor (RBI) for different countries. Such factor for the related countries are shown in Table 9, which is a good indicator for the comparison of different nations in term of cited publications.

A relation between the enterprise and research development (BERD) investment and the output of Ph.Ds and full time employed researchers is also given by King (2004). Such data is a useful measure for the interaction of knowledge transfer between business and higher education and therefore it is quoted for different countries in Table 9 of this report.

Table 9: Comparison of total publications, total citations, laser publications and patents (this study) and WI for different countries (King, 2004)

Country	Pub. (%) 1993-2001	Cit. (%) 1993-2001	Laser Pub. (%) 1990-2003	Laser Pat. (%) 1990-2003	Com. (%) 1993-2001	RBI 1993-2002	CI 1993-2002	WI 1995 US$	WI As (%) of GDP	Ph.Ds Per Pop.98-00	Res. 1997-2001
USA	**36.16**	**50.86**	**24.10**	15.000	**64.18**	**1.41**	0.25	**35.0**	1.97	0.17	8.17
UK	9.36	11.13	4.03	1.070	11.95	1.21	0.38	26.0	1.22	0.19	5.02
Germany	8.40	9.41	8.70	5.400	9.49	1.15	0.20	28.0	1.66	**0.30**	5.93
Japan	8.98	7.99	20.50	**69.700**	6.46	0.90	0.12	26.0	**2.12**	0.08	**9.59**
France	6.25	6.63	0.61	0.050	6.45	1.07	0.22	26.0	1.38	0.17	5.99
Italy	3.81	4.05	2.06	0.210	3.81	1.07	0.14	25.5	0.53	0.06	3.09
Spain	2.61	2.25	0.93	0.050	1.71	0.89	0.16	21.5	NA	NA	NA
Israel	1.26	1.29	0.77	0.230	1.40	1.05	**0.52**	21.0	NA	NA	NA
Russia	3.52	1.33	4.41	0.870	1.19	0.40	0.07	6.5	0.72	NA	NA
Finland	0.91	1.08	0.37	0.050	0.99	1.20	0.43	28.0	NA	NA	NA
China	2.62	1.27	5.60	0.770	0.71	0.51	0.03	4.0	NA	NA	NA
S. Korea	1.17	0.66	1.35	1.370	0.53	0.06	0.06	16.0	NA	NA	NA
India	2.16	0.81	1.06	0.002	0.43	0.40	0.02	2.5	NA	NA	NA
Brazil	1.02	0.61	0.41	0.002	0.39	0.62	0.03	7.0	NA	NA	NA
Ireland	0.32	0.30	0.07	0.008	0.30	0.93	0.12	32.0	NA	NA	NA
Greece	0.55	0.36	0.30	0.006	0.26	0.67	0.10	18.0	NA	NA	NA
Iran	0.08	0.04	0.06	0.000	0.02	0.44	0.01	6.0	NA	NA	NA

Pub: Percentage of publications, Cit: Percentage of citations, Laser Pub: percentage of laser publications, Laser Pat: Percentage of published laser patents, Com: Percentage of comparator group, RBI: Re-based impact factor, CI: Citation intensity, WI: Wealth intensity, GDP: Gross domestic product, BERD: Business enterprise research and development share as percentage of GDP, Ph.Ds: Number of Ph.Ds per head of population as a result of BERD share, Res: Full time researchers per 1000 employed as a result of BERD share, NA: Data not available

The ability to judge a nation's scientific standing and impacts is important for the government, companies and business that decide scientific priorities for funding. Looking at results shown in Table 9, one can see the share of top nations in total scientific publications and in particular laser publications in term of their GDP and national wealth. It is noted that the four countries including the USA, Japan, Germany and China have a contribution of 58.9% while the rest of the world including 189 countries contributes 41.1%. However, for the case of patent, which is a more important factor, these four countries hold a share of 90.1% while the remaining nations (189) have a small share of 9.9% (Table 1). As can be seen in Table 9, the US heads all the nations in the number of total scientific publications, citations and laser publications, however, in terms of accepted laser patents Japan shows a big lead. Another point is that laser publications and patents do not follow the orders shown in Table 9 for total publications and listed countries have different performances in this particular field of research.

Comparison of citations across 31 countries given as the comparator group in (King, 2004) and is represented in Table 9 for the 21 countries in the same order. In the comparator group of 31 countries the USA leads in the list of share of top 1% of the cited publications. As can be shown in Table 9, the USA has the highest percentage of citations 62.76%, United Kingdom 12.78%, Germany 10.4%, Japan 6.9%, France 6.85%, China 0.99% and South Korea 0.78% are respectively after US. According to that report these 31 countries have a share of about 98.5% while the world's remaining 162 countries have a contribution of about 1.5%.

The re-based impact factor, RBI, citations per papers is a useful number and is shown in Table 9 for the high-ranking countries. This is the average RBI over all scientific fields among all the 31 nations for the period of 1993-2002 (average world RBI is chosen equal to one in this analysis). As shown the USA has the highest RBI of (1.41), UK second (1.21), France (1.07), Japan (0.90), South Korea (0.61) and finally China (0.51) in the given list. These numbers are indicative of the citation rate per paper normalized to show Re-Based Impact (RBI) for such group nations. As can be noted the USA holds the highest RBI factor and there is correlation between the laser publications and this factor.

For showing the economic situation of involved countries as described in (King, 2004), the relation between the scientific wealth, national science citation intensity and the national Wealth Intensity (WI) is reported. Parameter CI is considered as the ratio of the citations to all papers to the national GDP while WI is defined in thousands of US dollars at 1995 purchasing power. Looking at Table 9 shows that there is a direct relation between the laser publications and the national wealth. In BERD, the US is leading with the R and D investment of 169228 million US dollars and Japan in second place with the contribution of 65726 M dollars. This shows strong economic situation of the US and Japan. Considering this BERD in terms of the percentage of GDP, this factor is shown in Table 9. Japan is leading in this respect (2.12%), the US in second (1.97%) while Italy (0.53%) is in the last place across listed G8 nations. With this contribution as can be in Table 1, one expect the highest percentage of laser publications as a result of R and D in this two countries.

Finally, the number indicating the full time researchers per 1000 employed as a result of BERD share is shown in Table 9. It is an important factor to have qualified experts to perform outstanding R and D programs. In this area Japan is the leader (9.59) and US is in second position (8.17). This figure shows out of 1000 employed personnel 9.59 people hired as researchers, which are defined as professionals engaged in the conception or creation of new knowledge, products, procedures, methods and systems and also in the management of the projects concerned. In the number of full time employed researchers Japan heads all the nations while Italy has the lowest rank.

Looking at Table 9 it is noticed that Iran has a scientific publication share of 0.08%, citation of 0.04 % and the laser publication of 0.06% and zero percentage of field patents for the period of 1990-2003. In the comparator group of 31 nations Iran has a share of about 0.02% in citations and ranking order of 30 among 1% of highly cited publications. The RBI factor is about 0.44, which is below the world average RBI = 1 and the CI factor of about 0.01. With these outcomes in publications the economic condition factors are as follows. The wealth intensity of Iran estimated to be 6 in the given scale and the contribution of BERD is negligible for this country and other information about involved Ph.Ds and researches are not available.

CONCLUSION

Trend of laser research developments in global level was presented in our recent report (Golnabi, 2006). It is important to recognize that there is a correlation in research funding and output outcomes. For the countries holding the top eight places, the science citation rank order produced about 84.5% of the top 1% most cited publications between 1993 and 2001, only 31 of the world's 193 countries produce 98.5% of the world's most cited papers. Considering the WI factor, which is related to spending economy, the US owns the highest wealth intensity while China has the minimum in the presented list (Table 9). The scope of laser research in Iran and nation wide have been also presented. For better understanding and judgment in this respect we need to consider our inputs and outputs in a more clear and scientific bases in order to make a decisive decision about the efficiency of laser research program in Iran. Even though in terms of WI our outcome looks promising, however we need to pay more attention to this important field and also possible potentials. As can be shown in Table 9, most developed countries have made a huge investment in the laser research programs and as a result have found many interesting results. This motivates more and more research in this field, but the limited budget for the whole science projects encourages different countries for an optimum spending, which also should include Iran.

The results of this study, clearly shows our standing and our ranking in terms of nation wide accomplishments. In publishing papers in this field our contribution is about 0.06% while for the field patent is close to zero (Table 1) and the international patent to paper ratio is practically zero. This requires more attention and guidance for a better outcome and more prestigious patent citations. I liked to have a precise number for the research funding for this period in order to give the turn over/capital cost figure. Unfortunately it is hard to extract accurate numbers for the projects resulted the publications for several reasons. The average annual growth for laser publications in global sense is about 6.66% while our annual growth is about 29.46%, which is reasonable considering our inputs and resources. However, the averaged annual growth of laser patents for the period of 1990-2003 is about 25% while for Iran is zero percent. If we want to see more contributions from the laser research in practical sense we need to improve our performance in this respect.

There is a high hope that in future to be able to devise integrated optics including the laser and other optical components in a more compact way. Such development requires the more advancement in the implementation of laser devices into new photonics nanostructures suitable for nanotechnology. In practice many hurdles need to be overcome before one feels a break through in the worldwide applications of new laser systems. The major problems and hurdles in laser area are mainly technical along with the high costs. Some important issues are:

- To be able to control the production process and manufacturing high quality lasers.
- Know how to produce small features for small sized lasers and how to manipulate those elements in nanostructure scales.
- Need to know how to handle mass production of electric, electronic and optical components of lasers suitable for the integrated circuits and integrated optics at lower costs.
- Some lasers are hard to use because of high maintenance cost, which need to be improved in terms of requiring pure gases or other consuming materials.
- There is a need for mass production in order to make fabrication process more cost effective.

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