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LASER Research in India: A Scientometric Study during 2004-2023

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Abstract

The study aims to analyze the growth, impact, and trends in LASER research in India from 2004 to 2023. Methodologically, the study uses bibliographic data from the Scopus database, examining 38,313 publications. Scientometric tools like RStudio (BiblioShiny) and VOS viewer were employed for citation-based and network analyses, visualizing collaborative and thematic networks. The findings reveal a 9.68% annual growth rate in publications, with contributions spread across 3,685 sources. Collaborative efforts are significant, with 6.06 co-authors per document and a 23.48% international co-authorship rate. The Raja Ramanna Centre for Advanced Technology leads institutional contributions (1,271 publications), and key authors like Choudhary R.J. significantly drive research output. This study provides valuable insights into the dynamic nature of LASER research in India, highlighting interdisciplinary impacts, active collaboration, and significant contributions to global scientific advancements, positioning India as a leader in LASER.

Keywords: Author Productivity, LASER Research, Network Visualization, Publication Trends, Scientometric Study

1. Introduction

LASER, or "Light Amplification by Stimulated Emission of Radiation," produces a focused light beam through optical amplification, revolutionizing fields such as medicine, communications, and manufacturing. Key milestones since its invention in 1960 include the first semiconductor LASER in 1962, LASER eye surgery in the 1980s, and fiber optic communications in the 1990s. In India, LASER research fuels innovation in healthcare, strengthens communication networks, and enhances manufacturing, supporting economic growth and positioning the country as a leader in advanced technologies and global competitiveness.

2. Review of the Related Literature

Zhu et al. (2021) explored advancements in LASER cladding, enhancing alloy durability for industrial applications. Yan et al. (2023) reviewed LASER micro-welding, showcasing its precision in manufacturing. Together, these studies emphasized LASER's evolving role in improving efficiency and material strength in sectors like automotive and aerospace engineering. Khalkhal et al.

(2019) highlighted LASER's transformative impact in oncology and dermatology, enabling precise, minimally invasive surgeries. Makkizadeh (2020) expanded on LASER's biomedical applications, emphasizing safety concerns and the need for ongoing evaluation to ensure efficacy as LASER technology became more prevalent in diagnostics and treatments.

Trofimenko (1987) used nuclear physics to show how scientometric methods tracked scientific growth, including LASER research, this studies highlighted the importance of interdisciplinary collaboration and advancing methodologies to expand LASER's impact. Czerwon (1990) utilized scientometric indicators, including Monte Carlo methods, to track developments in high-energy physics, which are also applicable to LASER research. Dutta and Rath (2013) examined trends in carbon nanotube research in India. Additionally, Tunga, S. K., Halder, M., and Jash, S. (2022), along with Paul, S. and Dutta, B. (2024), as well as Lawson et al. (1980), emphasized the effectiveness of bibliometric methods for monitoring various fields of research. Acharyya and Prakash (2021) discussed D. Narayana Rao's contributions to optics and photonics, underscoring India's rising influence in global LASER research. Jain and Garg (1992) conducted an early scientometric analysis, pinpointing growth areas and future directions for LASER research in India. Rajendiran and Parihar (2007) documented a consistent increase in research output from 1995 to 2005, highlighting the role of institutional collaborations. Garg (2002) compared LASER research in India and China, stressing the need for ongoing investment. Surwase, Kademani, and Kumar (2008) explored global collaboration networks in pulsed LASER deposition, promoting research progress. The literature underscored the importance of ongoing research, interdisciplinary collaboration, and methodological advancements in continuing to expand the boundaries of LASER.

3. Objectives of the Study

The six objectives for the study are as follows:

- To assess the annual growth rate of LASER research in India from 2004 to 2023, identifying trends in scientific output.
- To analyse the contributions of different institutions and geographic regions within India to LASER research, highlighting key contributors.
- To explore collaboration patterns among authors, institutions, and international partners, focusing on co-authorship and network strength.
- To identify the leading authors and key journals in LASER research, assessing their impact and influence in the field.
- To categorize the research output into various scientific disciplines, identifying core subject areas that dominate LASER research in India.

4. Research Methodology

For this study, bibliographic data on LASER was gathered from the Scopus database on July 22, 2024, at Calcutta University Central Library using the search criteria (TITLE-ABS-KEY(LASER) AND PUBYEAR > 2003 AND PUBYEAR < 2024 AND (LIMIT-TO (AFFILCOUNTRY, "India"))), resulting in 38,313 publications. The Scopus database is renowned for its extensive coverage of scientific fields. Data analysis was conducted using spreadsheet applications and RStudio (BiblioShiny) alongside VOSviewer for network

visualization, examining India's contributions to LASER research from 2004 to 2023.

5. Analysis and Discussion

The collected data has been analyzed and reported in the following tables. Some of the findings of the study are discussed below:

5.1 General information about study

Table 1 presents findings from a scientometric analysis of LASER research in India (2004-2023), showing rapid growth with 38,313 publications and an annual increase of 9.68%. These works were published across 3,685 sources, with an average of 17.21 citations per document, reflecting moderate impact. Collaboration is strong, with 6.06 co-authors per paper and 23.48% international co-authorship. Notably, 901 papers were single-authored. Keywords Plus (79,033) and Author's Keywords (33,957) illustrate the diverse research topics in the field.

Table 1: Key information about LASER publications

Description	Results
Time span	2004:2023
Sources (Journals, Books, etc)	3685
Documents	38313
Annual Growth Rate %	9.68
Document Average Age	9.31
Average citations per doc	17.21
References	659422
Keywords Plus (ID)	79033
Author's Keywords (DE)	33957
Authors	43961
Authors of single-authored docs	651
Single-authored docs	901
Co-Authors per Doc	6.06
International co-authorships %	23.48

5.2 Growth of publications

Table 2 shows the year-wise growth of LASER research publications in India from 2004 to 2023, with a clear upward trend. Starting with 637 articles in 2004, the total reached 38,313 by 2023, reflecting sustained growth. The annual share of total publications rose from 1.66% in 2004 to 9.72% in 2023. A notable 7.68% increase occurred between 2018 and 2019. Contributions in 2021-2023 were especially high, underscoring India's growing influence in global LASER research.

Table 2: Yearly distribution of publication counts

Year	Growth of Literature	Cumulative Growth of Literature	Year-wise % of total Publication Share
2004	637	637	1.66
2005	649	1286	1.69
2006	789	2075	2.06
2007	854	2929	2.23
2008	1076	4005	2.81
2009	1108	5113	2.89
2010	1277	6390	3.33
2011	1484	7874	3.87
2012	1562	9436	4.08
2013	1747	11183	4.56
2014	2011	13194	5.25
2015	1985	15179	5.18
2016	2174	17353	5.67
2017	2275	19628	5.94
2018	2499	22127	6.52
2019	2944	25071	7.68
2020	2948	28019	7.69
2021	3196	31215	8.34
2022	3374	34589	8.81
2023	3724	38313	9.72

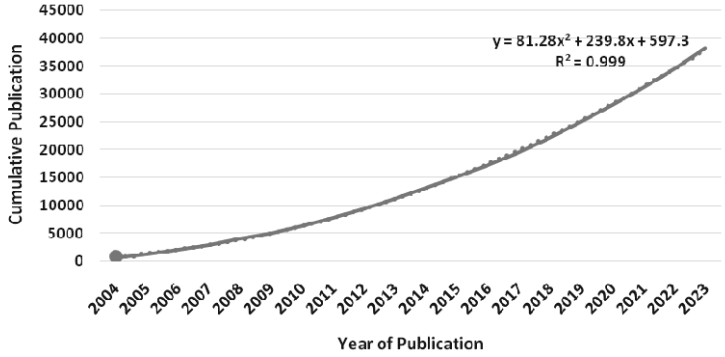

Figure 2: Cumulative growth trend curve of the literature

Figure 2 depict the cumulative growth curve for LASER research in India from 2004 to 2023. Figure 2 shows a cumulative publication trend following a quadratic model ($y = 81.289x^2 + 239.85x + 597.31$) with an R^2 of 0.9998, indicating an excellent fit. The quadratic growth highlights accelerating publication rates, suggesting increasing interest and investment. The high R^2 value confirms the model's accuracy in explaining the data variability.

5.3 Analysis of author productivity and co-authorship network visualization

Table 3 lists the top 20 Indian authors in LASER research by publication count. Choudhary, R.J. leads with 185 publications, followed by Philip, R., and Vinitha, G., each with 155. These prolific authors are key contributors to the field's growth, driving innovation and advancements. Several authors, including Kukreja, L.M. (131), and Vasa, N.J. (129), reflect a strong academic presence. The high output highlights India's robust research environment and significant role in advancing global LASER research.

Table 3: Analysis of core authors

Sl. No.	Authors' name	No. of Publication	Sl. No.	Authors' name	No. of Publication
1	Choudhary, R.J.	185	11	Kukreja, L.M.	131
2	Philip, R.	155	12	Vasa, N.J.	129
3	Vinitha, G.	155	13	Tripathi, V.K.	128
4	Phase, D.M.	149	14	Gupta, P.D.	125
5	Kant, N.	145	15	Pal, M.	117
6	Paul, M.C.	144	16	Khare, A.	112
7	Ramasamy, P.	144	17	Das, S.	109
8	Bindra, K.S.	143	18	Kalainathan, S.	109
9	Nampoori, V.P.N.	142	19	Rai, A.K.	108
10	Mathur, D.	132	20	Tomar, M.	108

The analysis of author productivity in LASER research, based on Lotka's Law, shows that a small group of authors produce most publications, a typical pattern in scientific output. Table 4 and Figure 3 depict this skewed distribution, with single authors contributing 25,451 publications (66.43% of total output), followed by two-author collaborations at 14.75%. Productivity decreases with more co-authors, as those with over ten publications represent just 0.40%. This emphasizes the dominance of prolific researchers and the need for increased collaboration.

Table 4: Author productivity based on Lotka's Law

No. of Author	No. of Publication	Percentage of Publication
1	25451	66.43
2	5653	14.75
3	3145	8.21
4	1307	3.41
5	853	2.23
6	585	1.53
7	386	1.01
8	339	0.88
9	246	0.64
10	193	0.50
>10	155	0.40

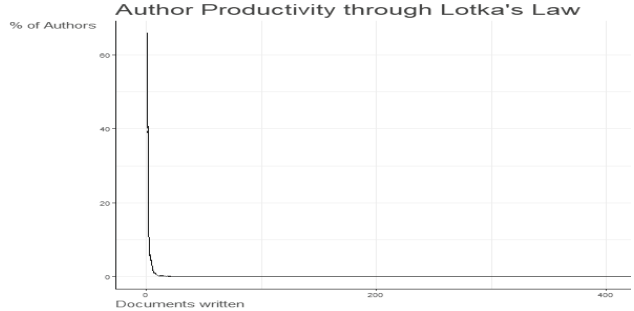

Figure 3: Author productivity curve according to Lotka's Law

Figure 4 visualizes the network of India's most prolific authors in LASER research, highlighting citations and link strength. Naik, P.A. leads with 1,261 citations and a link strength of 504, indicating strong influence and collaboration. Gupta, P.D. follows with 1,270 citations and 497 link strength, while Paul, M.C. has 625 citations and 402 link strength, reflecting their importance. Notable contributors like Kukreja, L.M. (2,793 citations) and Choudhary, R.J. (2,080 citations) also show strong academic ties, enhancing the field's impact.

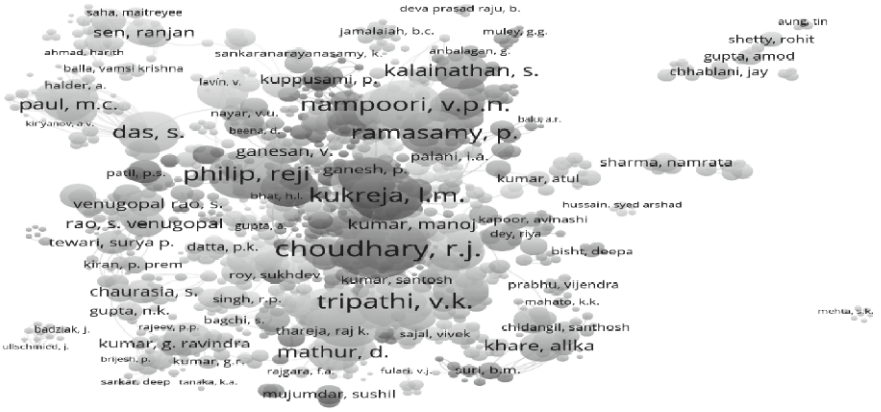

Figure 4: Visualization of the co-authorship network mapping

5.4 Analysis of core subject Area

Table 5 and Figure 5 present a performance analysis of core LASER research areas in India. Physics and Astronomy lead with 16,802 publications, emphasizing the foundational role of physics in LASER development. Materials Science (13,427) and Engineering (13,126) contribute significantly, reflecting LASER applications in material processing and innovation. Chemistry (6,382) and Medicine (5,784) showcase interdisciplinary uses, from chemical analysis to medical treatments. The broad scope, including Computer Science (3,059) and Environmental Science (970), highlights LASER's wide-reaching impact and India's leadership in the field.

Table 5: Subject areas covered in LASER research

Sl. No.	Subject	No. of Publication	Sl. No.	Subject	No. of Publication
1	Physics and Astronomy	16802	15	Agricultural and Biological Sciences	702
2	Materials Science	13427	16	Earth and Planetary Sciences	650
3	Engineering	13126	17	Multidisciplinary	550
4	Chemistry	6382	18	Neuroscience	378
5	Medicine	5784	19	Social Sciences	300
6	Biochemistry, Genetics and Molecular Biology	3534	20	Business, Management and Accounting	296
7	Computer Science	3059	21	Decision Sciences	267
8	Chemical Engineering	2772	22	Health Professions	206
9	Mathematics	1644	23	Economics, Econometrics and Finance	95
10	Pharmacology, Toxicology and Pharmaceutics	1470	24	Veterinary	49
11	Energy	1096	25	Nursing	41
12	Environmental Science	970	26	Psychology	32
13	Immunology and Microbiology	933	27	Arts and Humanities	22
14	Dentistry	716			

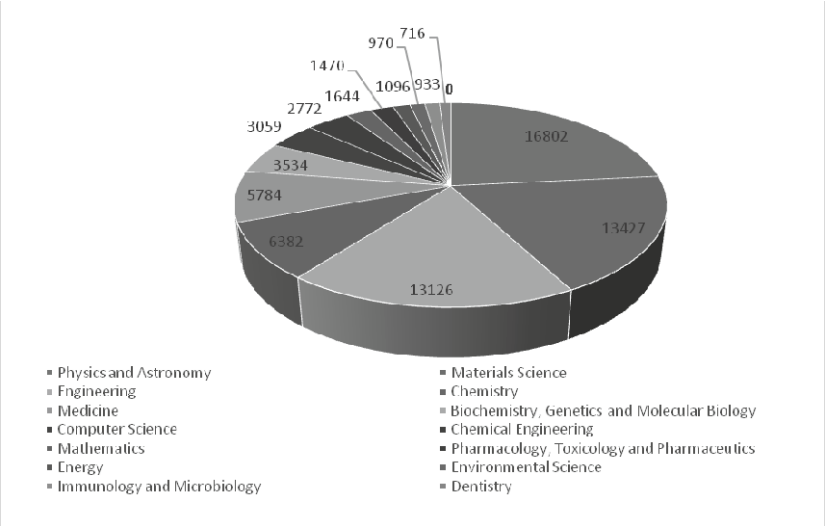

Figure 5: Distribution of subject areas covered

5.5 Analysis of core journal (sources)

Table 6 reveals that AIP Conference Proceedings leads Indian LASER research with 806 publications, underscoring its role in sharing cutting-edge findings. Materials Today Proceedings (669) and Proceedings of SPIE (558) also contribute significantly, reflecting a focus on materials and optical engineering. Optics and Laser Technology (440) and Optik (498) emphasize the importance of optical sciences. The presence of journals like the Indian Journal of Ophthalmology (407) highlights LASER research's multidisciplinary impact, enhancing India's global visibility and influence in the field.

Table 6: Distribution of core journals (sources)

Sl. No.	Journal	No. of Publication	Sl. No.	Journal	No. of Publication
1	AIP Conference Proceedings	806	11	Journal of Materials Science Materials in Electronics	314
2	Materials Today Proceedings	669	12	Spectrochimica Acta Part a Molecular and Biomolecular Spectroscopy	287
3	Proceedings of SPIE The International Society for Optical Engineering	558	13	Optics Communications	269
4	Optik	498	14	Journal of Alloys and Compounds	267
5	Optics and Laser Technology	440	15	Applied Optics	227
6	Indian Journal of Ophthalmology	407	16	Applied Physics Letters	227
7	Journal of Applied Physics	388	17	Lecture Notes in Mechanical Engineering	225
8	Optical Materials	377	18	Pramana Journal of Physics	215
9	Optics Infobase Conference Papers	356	19	Journal of Physics Conference Series	214
10	Physics of Plasmas	355	20	Applied Surface Science	211

5.6 Analysis of contributions by core institutions

Table 7 highlights key Indian institutions in LASER research, with the Raja Ramanna Centre for Advanced Technology leading at 1,271 publications (3.32%), underscoring its significant role in advancing LASER technologies. The Bhabha Atomic Research Centre (1,238, 3.23%) and Indian Institutes of Technology, such as IIT Madras (1,201, 3.13%) and IIT Delhi (1,168, 3.05%),

also contribute substantially, reflecting strong outputs in engineering and physical sciences. Institutions like the Indian Institute of Science (1,152, 3.01%) and AIIMS (603, 1.57%) showcase LASER's interdisciplinary impact.

Table 7: Distribution of core institutions

SL No.	Institutions	No. of Publications	Percentage
1	Raja Ramanna Centre for Advanced Technology	1271	3.32
2	Bhabha Atomic Research Centre	1238	3.23
3	Indian Institute of Technology Madras	1201	3.13
4	Indian Institute of Technology Delhi	1168	3.05
5	Indian Institute of Science	1152	3.01
6	Indian Institute of Technology Kharagpur	977	2.55
7	Indian Institute of Technology Bombay	917	2.39
8	Indian Institute of Technology Kanpur	880	2.30
9	University of Hyderabad	784	2.05
10	University of Delhi	741	1.93
11	Vellore Institute of Technology	672	1.75
12	Homi Bhabha National Institute	671	1.75
13	Tata Institute of Fundamental Research, Mumbai	632	1.65
14	All India Institute of Medical Sciences, New Delhi	603	1.57
15	Council of Scientific and Industrial Research India	600	1.57
16	Indian Institute of Technology Guwahati	530	1.38
17	Manipal Academy of Higher Education	525	1.37
18	Indira Gandhi Centre for Atomic Research	489	1.28
19	Anna University	489	1.28
20	CSIR-National Physical Laboratory	459	1.20

Figure 6 depicts the network mapping of key Indian institutions in LASER research, focusing on research output, citation impact, and link strength. The Tata Institute of Fundamental Research (Mumbai) and the Department of Physics at Sri Venkateswara University (Tirupati) stand out with 1,244 and 1,973 citations, respectively. The University of Delhi's Department of Physics and Astrophysics also shows significant influence with 829 citations. Institutions like the Central Glass and Ceramic Research Institute and the University of Hyderabad highlight strong collaborations, emphasizing India's impactful role in global LASER research.

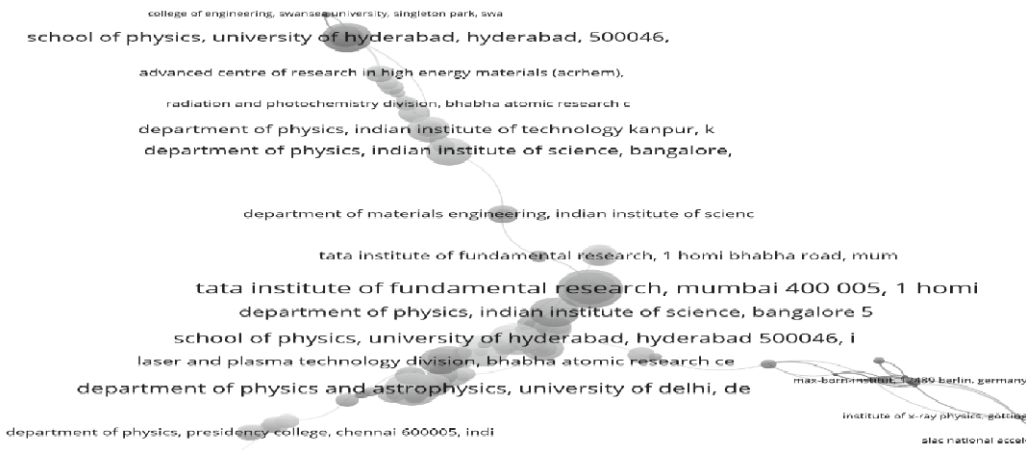

Figure 6: Visualization of the network mapping of core institutions

5.7 Analysis of published document types

Table 9 shows the form of publications in LASER literature and reveals that articles dominate, constituting 72.72% (27863) of the total publications. Conference papers follow at 17.10% (6,553), while reviews, book chapters, letters, and notes contribute with varying percentages. Books, errata, editorials, short surveys, retracted papers, data papers, and undefined forms represent smaller fractions. This diverse range of publication types reflects the multidimensional nature of LASER research, from in-depth articles and reviews to conference papers and book chapters.

Table 8: Document form types

Form of Publication	No of Publication	Percentage
Article	27863	72.72
Conference Paper	6553	17.10
Review	1874	4.89
Book Chapter	1106	2.89
Letter	452	1.18
Note	169	0.44
Book	90	0.23
Editorial	65	0.17
Erratum	64	0.17
Short Survey	51	0.13
Retracted	20	0.05
Data Paper	5	0.01
Undefined	1	0.00

5.8 Analysis of country collaboration and network mapping visualization

Table 9 reveals strong international collaborations in LASER research in India, with the United States leading at 2,237 partnerships, indicating significant scientific exchange and joint efforts. The United Kingdom (1,030) and Germany (1,002) also play key roles, showcasing robust ties with European institutions. Collaborations with Asian countries, including South Korea (689), China (664), and Japan (664), highlight regional cooperation in advancing LASER technologies. This extensive global network enhances the quality and impact of India's LASER research, promoting knowledge exchange and technological innovation.

Table 9: Analysis of international collaborations

SL No.	Country Name	No. of Collaboration	Sl. No.	Country Name	No. of Collaboration
1	United States	2237	11	Malaysia	331
2	United Kingdom	1030	12	Russian Federation	323
3	Germany	1002	13	Canada	322
4	South Korea	689	14	Taiwan	307
5	China	664	15	Singapore	281
6	Japan	664	16	Spain	280
7	Saudi Arabia	633	17	South Africa	229
8	France	556	18	Poland	226
9	Italy	507	19	Brazil	214
10	Australia	441	20	Netherlands	197

Figure 8 visualizes the network mapping of international collaborations in LASER research in India, showcasing strong global connections. The United States leads with the highest citations (73,940) and total link strength (2,536), highlighting its dominant role in collaborative efforts. Germany (47,955 citations) and the United Kingdom (43,439 citations) also demonstrate significant links, reflecting robust scientific exchanges. High link strengths from Japan, France, and Italy emphasize strong European and Asian partnerships. Collaborations with South Korea, China, and Australia further enhance India's global research impact, underscoring the importance of international partnerships in advancing LASER research and fostering innovation.

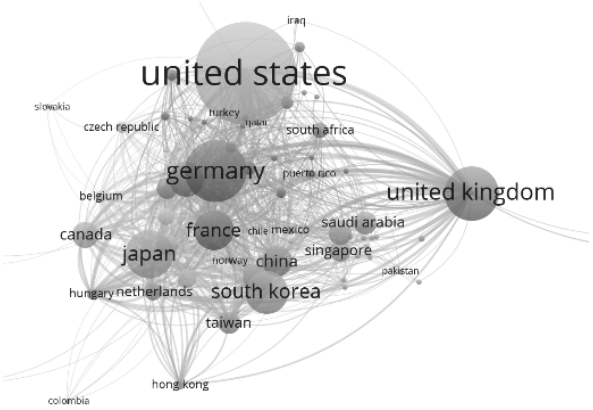

Figure 8: Network mapping visualization of India's core country collaborations.

6. Major Findings

The major findings of the study on LASER research in India (2004-2023) are as follows:

- ❖ Publications increased from 637 in 2004 to 38,313 in 2023, with an annual growth rate of 9.68%.
- ❖ Key research areas include Physics (16,802), Materials Science (13,427), and Engineering (13,126), showcasing interdisciplinary collaboration.
- ❖ Top contributors are the Raja Ramanna Centre for Advanced Technology (1,271) and Bhabha Atomic Research Centre (1,238).
- ❖ Prominent researchers include Choudhary R.J. (185) and Philip R. (155).
- ❖ International co-authorship is at 23.48%, led by the U.S. (2,237 collaborations).
- ❖ Major journals include AIP Conference Proceedings (806) and Materials Today Proceedings (669).

7. Conclusion

A scientometric analysis of LASER research in India from 2004 to 2023 reveals substantial growth, with contributions increasing at an annual rate of 9.68%. Key institutions, including the Raja Ramanna Centre for Advanced Technology, and prominent authors like Choudhary R.J. lead research in Physics, Materials Science, and Engineering. Collaboration networks, both domestic and international, significantly enhance the global impact of Indian LASER research. To sustain this progress, increased funding, interdisciplinary partnerships, and

investments in research infrastructure are essential, particularly in emerging fields like nanotechnology and biomedicine.

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