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Pro-Metrics

ORIGINAL ARTICLE

# Quantifying the influence of Indian optics research: An index based on three citation indicators

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**ABSTRACT**

**Objective.** This study aimed to identify and analyse the characteristics of highly cited papers (HCPs) in optics publications from India indexed in the Web of Science Core Collection database over the past 30 years. The analysis focused on document types, annual production and citations per publication, journals, countries, institutes, authors, and the top cited papers. The study also evaluated the publication performance of institutions and compared citation indicators of the most frequently cited articles.

**Design/Methodology/Approach.** The study used a bibliometric analysis approach and identified HCPs as documents cited 100 or more times by the Web of Science Core Collection from 1992 to 2021. Data were visualised using VOSviewer and Bibliometrix R packages. Citation indicators, including total citations and citations in 2021, were used to compare the most frequently cited articles.

**Results/Discussion.** The results showed that most highly cited papers were published in journals with high impact factors. The USA was the dominant country in collaboration with India in optics publications. The papers by Agostinelli *et al.* (2003) were the most frequently cited, and the paper by Aghanim *et al.* (2020) was the most impactful in 2021. The study also found that the Indian Institute of Technology, Delhi, was the leading institution in the number of highly cited papers produced.

**Conclusions.** This study provides insight into the characteristics and trends of highly cited papers in optics publications from India. The results highlight the importance of collaboration with the USA and the significance of publishing in high-impact factor journals. The study also indicates the need for institutions to focus on producing quality research to increase their publication performance and impact.

**Originality/Value:** This study contributes to the literature on bibliometric analysis by comprehensively analysing highly cited papers in optics publications from India. The study also provides insights into the collaboration patterns and publication performance of institutions in India. The findings can be used to inform policies and strategies aimed at improving research productivity and impact in India.

**Keywords:** optics; bibliometrics analysis; three citation indicator; highly cited paper; Web of Science; India.

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## 1. INTRODUCTION

Optics is the science of light. The term "optics" was originally used only for the eye and vision. Although it is not the eye that receives the light, but physical detectors such as photographic plates or television cameras, the meaning of the term optics was eventually extended to cover all uses of light. After that, when devices such as lenses that assist vision were developed, they naturally came to be called optical devices. Since optical techniques have been used extensively to study parts of the electromagnetic radiation spectrum not visible to the human eye, such as X-rays, ultraviolet, infrared, and microwave radio waves. These parts of the electromagnetic radiation spectrum are now frequently regarded as falling under the general category of optics (Kingslake & Thompson, n.d.).

Although the optics definition is related to the science of vision, optics generally encompasses a broader range of topics related to light and other regions of the electromagnetic spectrum. Optics in physics is essential in understanding how humans visualise the world ("Optics in Physics: Overview & Types| What Is Optics?," 2022).

Many unique research papers, reviews, and other documents focus on optics, eye and vision as obtained from the indexed papers in the Web of Science Core Collection databases during the last two decades (1992-2021). Systematic reviews or bibliometric studies can be consulted for research findings. Systematic reviews are limited in giving a general overview of a particular area. Bibliometric methods provide a systematic and objective analysis of written publications and mathematical and statistical methods, thereby presenting the knowledge base context, identifying research hotspots and pointing out emerging trends. There has been an increasing emphasis not only on quantitative data but more generally on qualitative aspects, such as the significance of bibliometric analysis in research evaluation. HCPs help us identify essential and cutting-edge research in a given field. Bibliometrics techniques have come to the rescue of readers and researchers by providing an effective method of analysing HCPs research (Ellegaard & Wallin, 2015).

## 2. RELATED LITERATURE

Few authors have conducted reviews on optics, eyes, or vision. Schargus *et al.* (2018) studied the 100 HCPs in the dry eye using the Web of Science database. All articles published on dry eye disease in 59 ophthalmological journals were identified. The top 100 articles were selected for further analysis based on authorship, journal origin, number of citations, rate of citations, geographical origin, type of article and level of evidence. This study gives researchers and clinicians a detailed outline of the most cited dry eye articles from 1983 to 2011. Schargus et al (2018), using the same database, analysed the top 100 HCPs published in 1991-2015 in macular imaging using optical coherence tomography. All these papers contain *'optical coherence tomography'* and *'retina'* including *'glaucoma'*. The study found the highest number of papers published in the 2000s, whereas the highest citations counted in the 1990s and the USA contributed the most papers.

Although the subjects related to optics/eye/vision research have received considerable attention in the literature. A few studies have been conducted throughout the years to map worldwide research trend subjects on optics (Kappi & Biradar, 2019, 2020; Marrugo, Bustos-González, & Rueda, 2022; Takeda & Kajikawa, 2009), quantum optics research (Gupta, Dhawan, & Mamdapur, 2021; Gupta *et al.*, 2022), HCPs in material science (B. Gupta, Dhawan, & Gupta, 2015; Ho, 2014) and optics journal (Kappi & Biradar, 2022). It is clear from above that the studies conducted so far have sought to focus their attention primarily on the quantitative and qualitative analysis of various research topics in India and also globally on highly cited research papers. Instead, this study will aim to look at the qualitative dimension of optics/eye/vision research in the country, measuring the most cited papers on optics/eye/vision papers published by India in the period 1992-2021 on a series of bibliometric indicators to understand the change of the research fieldover time.

## 3. METHODOLOGY

The scientometrics analysis of the HCPs published by India in Optics was conducted in September 2022. The data was retrieved from the

Web of Science Core Collection on September 27, 2022. We used the search query TS= (Optic* or Eye*) and CU=India; publication years from 1992 to 2021. A total of 89342 documents were retrieved. Among 1905 papers were identified as Highly Cited Papers (HCPs), cited≥ 100 times. The descriptive statistical analysis in this study was analysed by using MS Excel and scientometrics indicators: the number of citations, year-wise performance, single author, and collaborative publications were identified by the affiliation of the authors, first and last author, a total number of authors, name of the journal, geographical location, origin and associated institute, the title of the paper, type of document (paper or review), abstract and corresponding author.

The annual citation frequencies of all 1905 HCPs were collected. The number of citations of a publication in a single year, for example, 2021, is referred to as $C_{2021}$, and the total number of citations since publication to 2011 is called $TC_{2021}$. Citations received by a country more than once were not counted if several authors from different institutions but from the same country had participated in the same study. The number of papers per country was counted as long as an author from the country in the study. If the first author was affiliated with two institutions, the first institute was selected for inclusion.

### The Highly Cited Papers characterised using "Three Citation Indicators"

$TC_{year}$, proposed in 2011 (Chuang, Wang, & Ho, 2011; Wang, Fu, & Ho, 2011), is the number of citations in the Web of Science core collection from the year of publication to the end last year. For instance, $TC_{2021}$ denotes the citations from the year of publication until 2021. $C_{year}$ (Ho, 2012) is the number of citations in the last year. For instance, $C_{2021}$ specify the number of citations in 2021. $CPP_{year}$ is the number of citations per Paper ($CPP_{year} = TC_{year}/TP$) (TP: Total Publications/Papers).

### Visualised Analysis

The Bibliometrix R package and VOSviewer visualisation software enabled the analysis of the bibliometric visualisation of publications. This study used the VOSviewer and Biblioshiny for countries collaboration, institutions collaboration, co-occurrence, co-authorship, co-citation, and word cloud analysis.

## 4. OBJECTIVES OF THE STUDY

Finding the most highly referenced publications on Indian optical research is one of the main objectives of this study. The following are some of the work's specific goals:

a. identify the characteristics and citation pattern of top-cited papers using 'three citation indicators'.
b. to identify the year-wise distribution of HCPs in communication;
c. to recognise the significance of the field, their affiliated and country-wise contributions and to reveal the most productive journals;
d. to perform cluster analysis of author keywords using VOSviewer and biblioshiny software;

## 5. RESULTS

A total of 1905 (2.13 % of 89342) highly cited papers (HCPs) published during 1992-2021 were retrieved ( See Table 1). These 1905 HCPs with 31269 authors, ~3000 Institutions, 91 countries, and 546 sources/ journals were considered for more analysis. Most papers were produced in collaboration (97.7%), and single authors contributed only 44 (2.3%) papers. These 1905 HCPs counted 395191 at 207.45 average citations per paper (ACPP), and the document average age (Rørstad & Aksnes, 2015) was calculated at 12.6. Authors per paper were found to be 16.4 (n=780), 41% of papers were published in international collaboration (n=1081) 57% in intra-national collaboration. Average authors per paper, average co-authors per paper and an average number of papers per author suggested that have collaborated with two to sixteen authors. The average number of papers per author is less than one, and the number of author appearances is greater than the total number of authors, which shows that some authors have multiple publications. Further, these 1905 HCPs were scattered in various forms; 1558 papers, 300 review papers, 42 conference proceedings, 2 each as letter and note, and 1 in editorial material.

| Description | Results |
|---|---|
| Timespan | 1992-2021 |
| Sources (Journals, Books, etc) | 546 |
| Documents | 1905 |
| Annual Growth Rate % | -1.22 |
| Document Average Age | 12.6 |
| Total citations | 395191 |
| Average citations per doc | 207.45 |
| **DOCUMENT CONTENTS** | |
| Keywords Plus (ID) | 6711 |
| Author's Keywords (DE) | 3948 |
| **AUTHORS** | |
| Total authors | 31269 |
| Authors appearance | 20396 |
| Authors of single-authored docs | 42 |
| **AUTHORS COLLABORATION** | |
| Single-authored docs | 44 |
| Co-Authors per Doc | 16.4 |
| International co-authorships % | 40.94 |
| **DOCUMENT TYPES** | |
| Article | 1558 |
| Review | 300 |
| Conference Proceedings Paper | 42 |
| Letter | 2 |
| Note | 2 |
| Editorial Material | 1 |

**Table 1.** Summary of the Indian Optics research highly cited papers (HCP).

Amongst these 1905 HCPs, the top 29 HCPs with a $TC_{2021}$ of 1000 or more were identified. These 29 HCPs accounted for 17.04% of the $TC_{2021}$ and 8733 $C_{2021}$ (citations in 2021) citations. The top 29 HCPs included 17 papers and 12 reviews. The paper by Agostinelli *et al.* (2003) was ranked first with a $TC_{2021}$ of 15285, second in $C_{2021}$ and third in $CPP_{year}$ (citations per publication year) with 764.25 from 1992 to 2021. The second-ranked paper was by Peter AR *et al.* (2015) with a $TC_{2021}$ of 5413 and $CPP_{year}$ of 764.25, it was ranked fourth in $C_{2021}$ with 655 citations. In total, 7815 authors contributed to these 29 papers, with one paper published by a single author and four papers by two. Two papers were published by three, five, and six authors, respectively, and more than six authors published 16 papers. The paper by "Aasi *et al.* Advanced ligo in Classical and quantum gravity 32.7 (2015)" had the highest number of collaborators (n=607) and a $TC_{2021}$ of 1042, with contributions from more than100 institutions and was published in 23 journals. Of the 29 HCPs, 20 papers had citation counts ranging from 1000 to 2000, 5 papers ranging from 2000 to 3000, 2 papers ranged from 3000 to 4000, and 2 papers had counts of 5413 and 15285, respectively. Additionally, 16 papers were funded by Indian and foreign agencies and received a $TC_{2021}$ of 32090 at an ACPP (average citations per publication) of 2005.63.

### 5.1. Annual performance of Highly Cited Publications

According to WoS data, India produced 1905 HCPs in Optics during 1992-2021, which were cited at least 100 times from publication. India's HCPs output had a negative annual growth rate (-1.22%) during 1992-2021, and the yearly production varied from 10 in 1992 to 7 in 2021, with the highest number of papers (n=122) produced in 2009 and 2014, respectively. These 1905 HCPs were contributed by 32141 authors, among only 42 (0.13%) authors who contributed 44 papers in single authorship. This witnessed the significance of collaborative work at national and international levels. To the extent that it leads to publication, science funding contributes to the dissemination of knowledge and research publications and is thus an essential part of publicly funded science (Elango, 2017). Of the 1905 HCPs, nearly half of the total papers (n=868; 45.57%) were funded by various funding agencies. The funding agencies increased funding for research published in the last decade (in 2012-2021, funded 585 papers). DST was funded highest (n=216 papers), followed by CSIR funded (77 papers), UGC funded (45 papers), Science Engineering Research Board (SERB) India funded (10 papers), etc. These 868 funded HCPs received a total of 182121 citations at ACCP of 209.82.

Regarding the citations, the CPP of the 1905 HCPs is widely varied from 100 to 15285 per paper with an ACCP of 207.45. among them, 1818 (95.43%) papers counted citations between 100-500 each, 58 (3.04%) papers counted citations between 501-1000 each, 27 papers counted citations between 1001-5000 each, and the two papers received 5413 & 15285 citations each. In this study, the citation window was not set for the number of citations for the HCPs. Citation counts are based on total citations from 1992 to 2021 (Figure 1). Therefore, the number of citations of highly cited papers depended on time and varied from 1 to 1280 citations per year (1992-2021).

| S. No. | Document information | DOI | $TC_{2021}$ | $C_{2021}$(rank) | $CPP_{year}$(rank) |
|---|---|---|---|---|---|
| 1 | Agostinelli, Sea, *et al.* "GEANT4—a simulation toolkit." *Nuclear instruments and methods in physics research section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 506.3 (2003): 250-303. | 10.1016/S0168-9002(03)01368-8 | 15285 | 1280 (2) | 764.25 (3) |
| 2 | Ade, Peter AR, *et al.* "Planck 2015 results-xiii. cosmological parameters." *Astronomy & Astrophysics* 594 (2016): A13. | 10.1051/0004-6361/201525830 | 5413 | 655 (4) | 773.29 (2) |
| 3 | Rai, Mahendra, Alka Yadav, and Aniket Gade. "Silver nanoparticles as a new generation of antimicrobials." *Biotechnology advances* 27.1 (2009): 76-83. | 10.1016/j.biotechadv.2008.09.002 | 3858 | 311 (9) | 275.57 (5) |
| 4 | Chatrchyan, S., *et al.*"The CMS experiment at the CERN LHC." *Journal of Instrumentation* 3 (2008). | 10.1088/1748-0221/3/08/S08004 | 3343 | 144 (16) | 222.87 (8) |
| 5 | Aghanim, Nabila, *et al.* "Planck 2018 results-VI. Cosmological parameters." *Astronomy & Astrophysics* 641 (2020): A6. | 10.1051/0004-6361/201833910 | 2890 | 1783 (1) | 963.33 (1) |
| 6 | Gulshan, Varun, *et al.* "Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs." *Jama* 316.22 (2016): 2402-2410. | 10.1001/jama.2016.17216 | 2797 | 708 (3) | 399.57 (4) |
| 7 | Gupta, V. K. "Application of low-cost adsorbents for dye removal–a review." *Journal of environmental management* 90.8 (2009): 2313-2342. | 10.1016/j.jenvman.2008.11.017 | 2585 | 254 (11) | 184.64 (12) |
| 8 | Yau, Joanne WY, *et al.* "Global prevalence and major risk factors of diabetic retinopathy." *Diabetes care* 35.3 (2012): 556-564. | 10.2337/dc11-1909 | 2434 | 459 (5) | 221.27 (9) |
| 9 | Ghosh, Sujit Kumar, and Tarasankar Pal. "Interparticle coupling effect on the surface plasmon resonance of gold nanoparticles: from theory to applications." *Chemical reviews* 107.11 (2007): 4797-4862. | 10.1021/cr0680282 | 2106 | 147 (15) | 131.63 (16) |
| 10 | Peng, Juan, *et al.* "Graphene quantum dots derived from carbon fibers." *Nano letters 12.2 (2012): 844-849.* | 10.1021/nl2038979 | 1767 | 193 (12) | 160.64 (14) |
| 11 | Swarnkar, Abhishek, *et al.* "Quantum dot–induced phase stabilization of α-CsPbI3 perovskite for high-efficiency photovoltaics." *Science* 354.6308 (2016): 92-95. | 10.1126/science. aag2700 | 1765 | 348 (8) | 252.14 (7) |
| 12 | Abbott, Benjamin P., *et al.* "Estimating the contribution of dynamical ejecta in the kilonova associated with GW170817." *The Astrophysical Journal Letters* 850.2 (2017): L39. | 10.3847/2041-8213/aa91c9 | 1621 | 372 (7) | 270.17 (6) |
| 13 | Simon, Rajiah. "Peres-Horodecki separability criterion for continuous variable systems." *Physical Review Letters* 84.12 (2000): 2726. | 10.1103/PhysRevLett.84.2726 | 1600 | 92 (23) | 69.57 (24) |
| 14 | Eisenstein, Daniel J., *et al.* "SDSS-III: Massive spectroscopic surveys of the distant universe, the Milky Way, and extra-solar planetary systems." *The Astronomical Journal* 142.3 (2011): 72. | 10.1088/0004-6256/142/3/72 | 1526 | 119 (17) | 127.17 (19) |
| 15 | Alam, Shadab, *et al.* "The eleventh and twelfth data releases of the Sloan Digital Sky Survey: final data from SDSS-III." *The Astrophysical Journal Supplement Series* 219.1 (2015): 12. | 10.1088/0067-0049/219/1/12 | 1426 | 100 (20) | 178.25 (13) |
| 16 | Kango, Sarita, *et al.* "Surface modification of inorganic nanoparticles for development of organic–inorganic nanocomposites—A review." *Progress in Polymer Science* 38.8 (2013): 1232-1261. | 10.1016/j.progpolymsci.2013.02.003 | 1373 | 167 (13) | 137.30 (15) |

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| S. No. | Document information | DOI | $TC_{2021}$ | $C_{2021}$(rank) | $CPP_{year}$(rank) |
|---|---|---|---|---|---|
| 17 | Bhadra, Sambhu, *et al.* "Progress in preparation, processing and applications of polyaniline." *Progress in Polymer Science* 34.8 (2009): 783-810. | 10.1016/j.progpolymsci.2009.04.003 | 1365 | 98 (21) | 97.50 (22) |
| 18 | Chandran, S. Prathap, *et al.* "Synthesis of gold nanotriangles and silver nanoparticles using Aloevera plant extract." *Biotechnology progress* 22.2 (2006): 577-583. | 10.1021/bp0501423 | 1318 | 98 (22) | 77.53 (23) |
| 19 | Grogin, Norman A., *et al.* "CANDELS: the cosmic assembly near-infrared deep extragalactic legacy survey." *The Astrophysical Journal Supplement Series* 197.2 (2011): 35. | 10.1088/0067-0049/197/2/36 | 1300 | 115 (19) | 108.33 (20) |
| 20 | Harrison, Fiona A., *et al.* "The nuclear spectroscopic telescope array (NuSTAR) high-energy X-ray mission." *The Astrophysical Journal* 770.2 (2013): 103. | 10.1088/0004-637X/770/2/103 | 1279 | 157 (14) | 127.90 (18) |
| 21 | Flaxman, Seth R., *et al.* "Global causes of blindness and distance vision impairment 1990–2020: a systematic review and meta-analysis." *The Lancet Global Health* 5.12 (2017): e1221-e1234. | 10.1016/S2214-109X(17)30393-5 | 1278 | 426 (6) | 213 (10) |
| 22 | Mishra, Amaresh, *et al.* "Cyanines during the 1990s: a review." *Chemical reviews* 100.6 (2000): 1973-2012. | 10.1021/cr990402t | 1276 | 64 (25) | 55.48 (26) |
| 23 | Braga, Dario, Fabrizia Grepioni, and Gautam R. Desiraju. "Crystal engineering and organometallic architecture." *Chemical reviews* 98.4 (1998): 1375-1405. | 10.1021/cr960091b | 1220 | 18 (29) | 48.80 (28) |
| 24 | Murphy, Catherine J., and Nikhil R. Jana. "Controlling the aspect ratio of inorganic nanorods and nanowires." *Advanced Materials* 14.1 (2002): 80-82. | 1002/1521-4095(20020104) 14:1<80::AID-ADMA80>3.0.CO;2-# | 1164 | 20 (28) | 55.43 (27) |
| 25 | Chakraborty, Indranath, and Thalappil Pradeep. "Atomically precise clusters of noble metals: emerging link between atoms and nanoparticles." *Chemical reviews* 117.12 (2017): 8208-8271. | 10.1021/acs.chemrev.6b00769 | 1139 | 305 (10) | 189.83 (11) |
| 26 | Roy, Kallol, *et al.* "Graphene–MoS2 hybrid structures for multifunctional photoresponsive memory devices." *Nature nanotechnology* 8.11 (2013): 826-830. | 10.1038/NNANO.2013.206 | 1070 | 117 (18) | 107.00 (21) |
| 27 | Ramanathan, Veerabhadran, *et al.* "Indian Ocean Experiment: An integrated analysis of the climate forcing and effects of the great Indo-Asian haze." *Journal of Geophysical Research: Atmospheres* 106.D22 (2001): 28371-28398. | 10.1029/2001JD900133 | 1058 | 38 (27) | 48.09 (29) |
| 28 | Aasi, Junaid, *et al.* "Advanced ligo." *Classical and quantum gravity* 32.7 (2015): 074001. | 10.1088/0264-9381/32/7/074001 | 1042 | 84 (24) | 130.25 (17) |
| 29 | Mitra, Sushmita, and Tinku Acharya. "Gesture recognition: A survey." *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)* 37.3 (2007): 311-324. | 10.1109/TSMCC.2007.893280 | 1036 | 61 (26) | 64.75 (25) |

$TC_{2021}$=Citations since from the publication to till 2021; $C_{2021}$= Number of citations in 2021; $CPP_{year}$= Citations per Paper

**Table 2.** Three citation indicators.

| Year | TP | TA | SAP | AAPP | FP | %FP | TC | ACPP |
|---|---|---|---|---|---|---|---|---|
| 2021 | 7 | 505 | 0 | 72.14 | 6 | 85.714 | 1129 | 161.29 |
| 2020 | 21 | 440 | 1 | 20.95 | 11 | 52.381 | 5865 | 279.29 |
| 2019 | 43 | 698 | 1 | 16.23 | 31 | 72.093 | 6899 | 160.44 |
| 2018 | 66 | 847 | 1 | 12.83 | 53 | 80.303 | 10203 | 154.59 |
| 2017 | 93 | 8583 | 0 | 92.29 | 75 | 80.645 | 21858 | 235.03 |
| 2016 | 103 | 2890 | 2 | 28.06 | 76 | 73.786 | 26546 | 257.73 |
| 2015 | 111 | 1976 | 1 | 17.80 | 86 | 77.477 | 19811 | 178.48 |
| 2014 | 122 | 3770 | 4 | 30.90 | 93 | 76.230 | 21687 | 177.76 |
| 2013 | 106 | 866 | 1 | 8.17 | 68 | 64.151 | 23199 | 218.86 |
| 2012 | 114 | 666 | 3 | 5.84 | 86 | 75.439 | 24765 | 217.24 |
| 2011 | 115 | 940 | 1 | 8.17 | 87 | 75.652 | 21412 | 186.19 |
| 2010 | 111 | 1394 | 1 | 12.56 | 75 | 67.568 | 18475 | 166.44 |
| 2009 | 122 | 628 | 0 | 5.15 | 77 | 63.115 | 29807 | 244.32 |
| 2008 | 110 | 3257 | 2 | 29.61 | 35 | 31.818 | 21693 | 197.21 |
| 2007 | 96 | 433 | 1 | 4.51 | 2 | 2.083 | 19177 | 199.76 |
| 2006 | 96 | 385 | 1 | 4.01 | 0 | 0 | 17267 | 179.86 |
| 2005 | 69 | 644 | 4 | 9.33 | 1 | 1.449 | 14453 | 209.46 |
| 2004 | 72 | 625 | 3 | 8.68 | 0 | 0 | 14258 | 198.03 |
| 2003 | 59 | 347 | 5 | 5.88 | 1 | 1.695 | 27971 | 474.08 |
| 2002 | 46 | 189 | 1 | 4.11 | 1 | 2.174 | 9604 | 208.78 |
| 2001 | 39 | 309 | 1 | 7.92 | 0 | 0 | 9079 | 232.79 |
| 2000 | 41 | 156 | 2 | 3.80 | 1 | 2.439 | 12231 | 298.32 |
| 1999 | 29 | 191 | 2 | 6.59 | 1 | 3.448 | 4714 | 162.55 |
| 1998 | 25 | 157 | 2 | 6.28 | 0 | 0 | 6261 | 250.44 |
| 1997 | 27 | 111 | 2 | 4.11 | 0 | 0 | 4838 | 179.19 |
| 1996 | 18 | 54 | 1 | 3.00 | 0 | 0 | 3638 | 202.11 |
| 1995 | 17 | 54 | 0 | 3.18 | 0 | 0 | 3219 | 189.35 |
| 1994 | 8 | 28 | 0 | 3.50 | 2 | 25 | 1628 | 203.50 |
| 1993 | 9 | 24 | 0 | 2.67 | 0 | 0 | 1607 | 178.56 |
| 1992 | 10 | 34 | 1 | 3.40 | 0 | 0 | 1898 | 189.80 |
| 1992-2001 | 223 | 1118 | 11 | 5.01 | 4 | 1.794 | 49113 | 220.2376 |
| 2002-2011 | 896 | 8842 | 19 | 9.87 | 279 | 31.138 | 184116 | 205.4866 |
| 2012-2021 | 786 | 22181 | 14 | 28.22 | 585 | 74.427 | 161962 | 206.0585 |
| 1992-2021 | 1905 | 32141 | 44 | 16.87 | 868 | 45.564 | 395191 | 207.4493 |

**Table 3.** Year-wise trends of HCP in Indian Optics. Note: TP=Total Publications; TA=Total Authors; SAP= Single Author Papers; AAPP=Average Author per Paper; FP= Funded Papers; TC= Total Citations; ACPP=Average Citation per Paper.

### 5.2. Top 20 most collaborative countries

Of all the 1905 HCPs in Optics, 1861 papers were published in collaboration, in that 1425 papers were correspondence by Indian authors, 43 papers were single country publications, and these papers scored 394126 citations with ACPP of 210.71 during 1992-2021. These 1861 papers collaborated with various countries, among 302 (CAP=154) papers with the USA, 140 (CAP=29) papers with Germany, 126 (CAP=41) papers with England, etc. in terms of citations, the USA scored 103134 citations, followed by Germany (TC=62426), England (TC=61884), France (TC=51361), etc. however Switzerland has the higher citation impact (ACPP=930.36), followed by Russia (ACPP=867.45), Netherlands (ACPP=777.85), Spain (ACPP=699.77) and so on (Table 4).

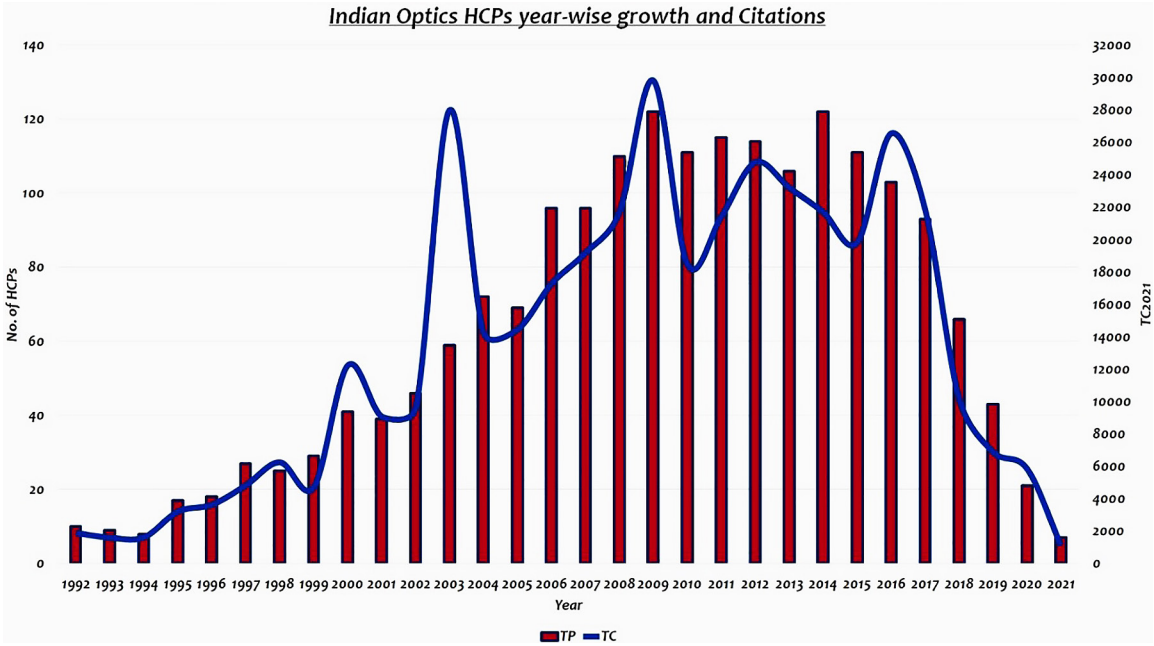


**Figure 1.** Indian HCP's year-wise growth and citations.

| No. | Country | TP | CAP | SCP | TC | ACPP | TLS |
|---|---|---|---|---|---|---|---|
| 1 | India | 1861 | 1425 | 43 | 392146 | 210.718 | 1658 |
| 2 | USA | 302 | 154 | 0 | 103134 | 341.503 | 1112 |
| 3 | Germany | 140 | 29 | 0 | 62426 | 445.900 | 790 |
| 4 | England | 126 | 41 | 0 | 61884 | 491.143 | 816 |
| 5 | France | 101 | 15 | 0 | 51361 | 508.525 | 672 |
| 6 | Japan | 100 | 30 | 0 | 46670 | 466.700 | 469 |
| 7 | Australia | 84 | 14 | 0 | 34050 | 405.357 | 519 |
| 8 | Italy | 82 | 11 | 0 | 53672 | 654.537 | 638 |
| 9 | South Korea | 80 | 27 | 0 | 18246 | 228.075 | 213 |
| 10 | China | 69 | 16 | 0 | 24524 | 355.420 | 390 |
| 11 | Canada | 62 | 10 | 0 | 42457 | 684.790 | 436 |
| 12 | South Africa | 58 | 11 | 0 | 21534 | 371.276 | 333 |
| 13 | Spain | 57 | 4 | 0 | 39830 | 698.772 | 530 |
| 14 | Netherlands | 52 | 6 | 0 | 40448 | 777.846 | 445 |
| 15 | Saudi Arabia | 50 | 14 | 0 | 8608 | 172.160 | 101 |
| 16 | Brazil | 45 | 6 | 0 | 17153 | 381.178 | 317 |
| 17 | Singapore | 44 | 18 | 0 | 12027 | 273.341 | 164 |
| 18 | Russia | 40 | 4 | 0 | 34698 | 867.450 | 377 |
| 19 | Switzerland | 39 | 3 | 0 | 36284 | 930.359 | 394 |
| 20 | Taiwan | 35 | 5 | 0 | 16470 | 470.571 | 222 |

**Table 4.** Top 20 most collaborative countries with India in Optics Research.
Note: TP=Total Publications; CAP=Corresponding Author Country Publications; SCP= Single Country Publications; TC=Total Citations; ACPP=Average Citation per Paper; TLS= Total Link Strengths.

The network visualisation map was constructed for the country-co-authorship of the 1905 HCPs (Figure 2). The core of this network was India, which collaborated with at least 35 papers. Of the 94 countries, 20 countries met the threshold. These 20 countries are spread over in 2 clusters; cluster 1 consists of 13 countries like Australia, Brazil, Canada, England, France, etc. Cluster 2 consists of 7 countries like, India, Japan, China, the USA etc. The top 20 countries have 188 links and 4948 total link strengths.

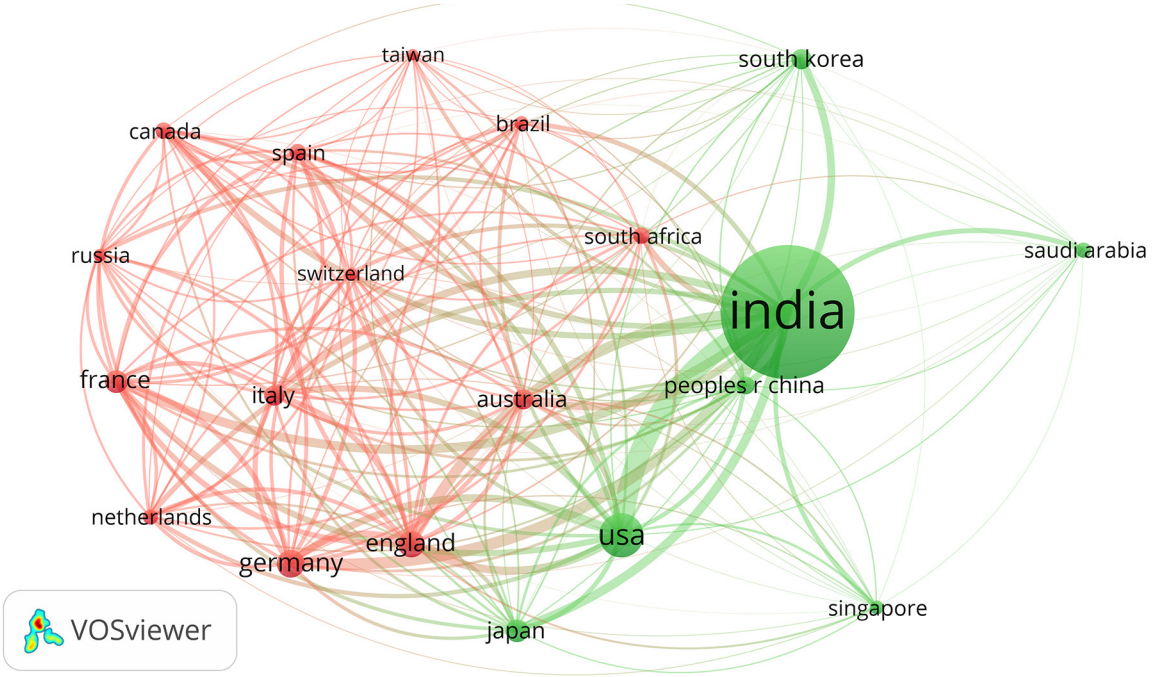


**Figure 2.** Indian Optics HCPs collaborative linkages with top-20 countries.

### 5.3. Performance of top-20 institutions in Indian optics research

A total of 3071 institutions contributed to Indian optics HCPs; among 2511 institutions, contributed 1-5 papers each, 290 institutions 6-10 papers each, 164 institutions 11-20 papers each, 89 institutions 21-50 each, 13 institutions 51-100 papers each, and 4 institutions 101-332 papers. The top 20 most productive institutions contributed 39-332 papers and together contributed 1636 (84.94%) papers and counted 387179 citations. Four institutions contributed HCPs above 81.8%, while six counted the ACPP above the group average. Table 5 depicts the top 20 most productive and impactful institutions in Indian optics HCPs.

Of the 3071 institutions, the minimum number of documents of an institute (n=15) and a minimum number of citations of an institute 500 were considered for the network map. One hundred one institutions met the thresholds. Among 101 institutions, the top 20 Indian institutes were selected using the VOSviewer tool. The network visualisation map of the top 20 institutions is spread into seven clusters. Cluster 1 includes AIIMS, BHU, L V Prasad Eye Institute, Sri Venkateswara University and The University of Hyderabad. Clusters 2, 3 and 4 consist of 3 three institutions each and clusters 5, 6 &7 consist of two, respectively. The size of the node indicates the importance of the institute. The size of the circle shows the significance of the institute. The distance between two nodes indicates the strength of the relationship between the two nodes. In general, the shorter the distance, the more evident the relationship. The line between the two institutes indicates that they appear together. The thicker the line, the more simultaneous it occurs, and nodes of the same colour belong to the cluster. Among the 20 institutions, IIT and IISc collaborate more, followed by IISc and JNCSAR institutes. These 20 institutes have 49 links and TLS of 104 (Figure 3).

| No. | Institutions | TP | % Of 1905 | TC | ACPP |
|---|---|---|---|---|---|
| 1 | Indian Institute of Technology System, India | 332 | 17.238 | 69326 | 208.81 |
| 2 | Council of Scientific Industrial Research, India | 256 | 13.292 | 54586 | 213.23 |
| 3 | Department of Science Technology, India | 157 | 8.152 | 34125 | 217.36 |
| 4 | Indian Institute of Science, Bangalore | 101 | 5.244 | 20140 | 199.41 |
| 5 | Indian Institute of Technology, Delhi | 63 | 3.271 | 10870 | 172.54 |
| 6 | Shivaji University, Kolhapur | 62 | 3.219 | 11202 | 180.68 |
| 7 | Department of Space, India | 59 | 3.063 | 29227 | 495.37 |
| 8 | L V Prasad Eye Institute, Hyderabad | 57 | 2.960 | 14385 | 252.37 |
| 9 | Tata Institute of Fundamental Research, Mumbai | 55 | 2.856 | 32155 | 584.64 |
| 10 | CSIR National Physical Laboratory, New Delhi | 51 | 2.648 | 10447 | 204.84 |
| 11 | Indian Association for the Cultivation of Science, Jadavpur | 50 | 2.596 | 8013 | 160.26 |
| 12 | Indian Institute of Technology, Kharagpur | 47 | 2.44 | 12024 | 255.83 |
| 13 | Sri Venkateswara University, Tirupati | 47 | 2.44 | 6905 | 146.91 |
| 14 | Bhabha Atomic Research Center, Mumbai | 46 | 2.388 | 19989 | 434.54 |
| 15 | CSIR National Chemical Laboratory, Pune | 46 | 2.388 | 11882 | 258.30 |
| 16 | National Institute of Technology, India | 44 | 2.285 | 7291 | 165.70 |
| 17 | Jawaharlal Nehru Center for Advanced Scientific Research, Bangalore | 43 | 2.233 | 9408 | 218.79 |
| 18 | Indian Institute of Technology, Kanpur | 41 | 2.129 | 7571 | 184.66 |
| 19 | CSIR National Institute Interdisciplinary Science Technology, Thiruvananthapuram | 40 | 2.077 | 9616 | 240.40 |
| 20 | Indian Institute of Technology, Bombay | 39 | 2.025 | 8017 | 205.56 |
| | **TOTAL** | **1636** | **84.944** | **387179** | **250.01** |

**Table 5.** Top-20 most performed institutions in Indian optics.
Note: TP=Total Publications; TC=Total Citations; ACPP=Average Citation per Paper.

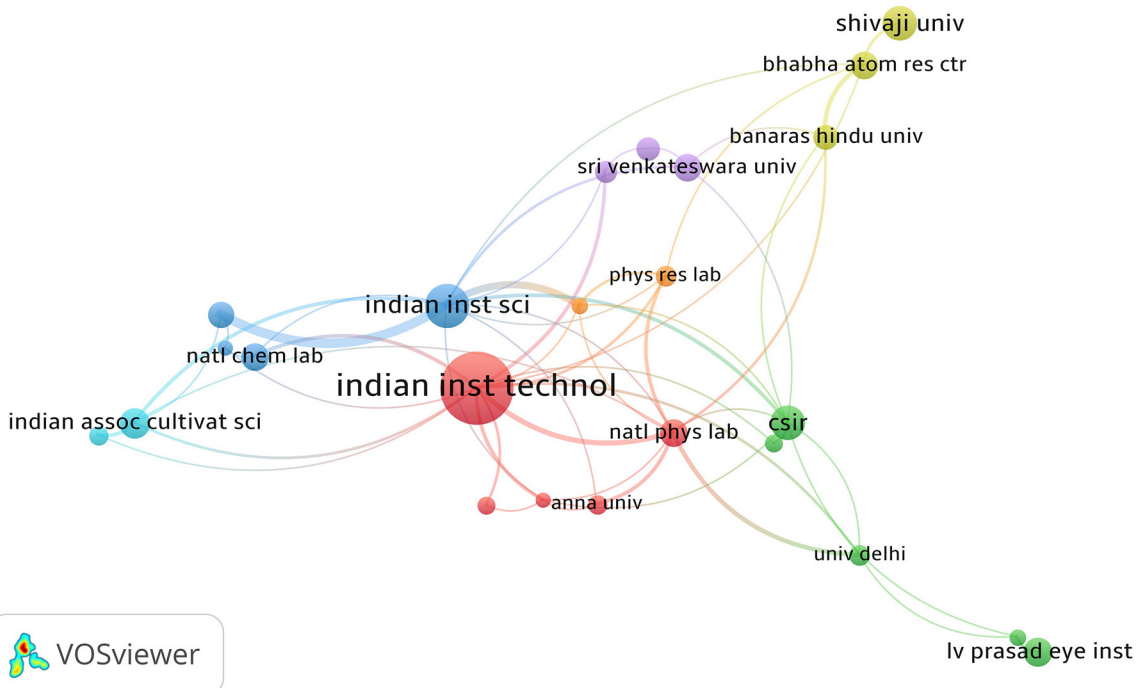


**Figure 3.** Collaboration network of the top 20 institutions.

### 5.4. Most productive authors and their influence on Indian optics research

A total of 31269 authors were involved in the 1905 Indian optics HCPs. Among 15907 authors have contributed one paper each, 2226 authors contributed two papers each, 746 authors three papers each, 524 authors four papers each, 345 authors five papers each, and one author contributed 33, 29, 21 & 18 papers each, two authors 25 & 15 papers each. The authors for a paper ranged between 1 to 3149 (Average Authors per Article: 16.4). Table 6 lists the top 20 most productive authors. These authors' contributions ranged from 14 to 33 papers, and all contributed 363 (19%) of the output. Analysis of the top 20 most productive authors based on their contributions in the 1905 HCPs, regardless of their authorship positions, that Kumar S (TP=33; TC=8336; CPP=252.61; h index=33) with the highest number of papers, followed by Kumar A (TP=29; TC=10410; CPP=359; h index=29), Kumar R and Kumar V (TP=25 each) etc. In terms of citations, these 20 authors counted citations ranging from 2153 to 21457 for their respective publications, and all received a total of 114575 (29% of the TC) at a CPP of 315.63. among them, Abir De Sarkar was the most impactful author with the highest TC 21457 and CPP 1341, followed by Ghosh A (TC=6760; CPP=422.5), Kumar A (TC=10410; CPP=359), etc.

| S. No. | Authors | Affiliations | TP | FAP | CAP | TC | CPP | h_index | g_index |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Kumar S | Guru Nanak Dev University, Amritsar | 33 | 7 | 9 | 8336 | 252.61 | 33 | 33 |
| 2 | Kumar A | Guru Nanak Dev University, Amritsar | 29 | 10 | 5 | 10410 | 358.97 | 29 | 29 |
| 3 | Kumar R | Panjab University, Chandigarh | 25 | 7 | 5 | 8223 | 328.92 | 25 | 25 |
| 4 | Kumar V | Delhi University, New Delhi | 25 | 11 | 8 | 4939 | 197.56 | 25 | 25 |
| 5 | Lokhande CD | Shivaji University, Kolhapur | 21 | 0 | 12 | 4578 | 218.00 | 21 | 21 |
| 6 | Das S | Bengal Engineering and Science University, West Bengal | 18 | 5 | 6 | 6424 | 356.89 | 18 | 18 |
| 7 | DE (Abir De Sarkar) | Institute of Nano Science and Technology, Mohali | 16 | 0 | 3 | 21457 | 1341.06 | 16 | 16 |
| 8 | Ghosh A | TERI University, New Delhi | 16 | 1 | 0 | 6760 | 422.50 | 16 | 16 |
| 9 | Singh S | Ahmedabad University, Ahmedabad | 16 | 7 | 5 | 5581 | 348.81 | 16 | 16 |
| 10 | Rao CNR | Jawaharlal Nehru Center for Advanced Scientific Research, Bangalore | 16 | 5 | 9 | 4405 | 275.31 | 16 | 16 |
| 11 | Patil PS | Bharati Vidyapeeth Deemed University | 16 | 4 | 0 | 2822 | 176.38 | 16 | 16 |
| 12 | Gupta BD | Institute of Nano Science and Technology, India | 16 | 3 | 14 | 2696 | 168.50 | 16 | 16 |
| 13 | Jayasankar CK | Sri Venkateswara University, Tirupati | 16 | 4 | 15 | 2222 | 138.88 | 16 | 16 |
| 14 | Pal T | Indian Association for the Cultivation of Science, New Delhi | 15 | 1 | 13 | 4935 | 329.00 | 15 | 15 |
| 15 | Gupta A | Postgraduate Institute of Medical Education and Research, New Delhi | 15 | 4 | 4 | 4412 | 294.13 | 15 | 15 |
| 16 | Sastry M | National Chemical Laboratory, Pune | 14 | 4 | 11 | 4706 | 336.14 | 14 | 14 |
| 17 | Dandona L | L V Prasad Eye Institute, Hyderabad | 14 | 8 | 8 | 2478 | 177.00 | 14 | 14 |
| 18 | Kumar M | Defence Institute of Advanced Technology, India | 14 | 3 | 7 | 2332 | 166.57 | 14 | 14 |
| 19 | Rao GN | L V Prasad Eye Institute, Hyderabad | 14 | 2 | 1 | 2153 | 153.79 | 14 | 14 |
| 20 | Sastry M | National Chemical Laboratory, Pune | 14 | 4 | 11 | 4706 | 336.14 | 14 | 14 |

**Table 6.** Top-20 most productive authors and their impact. Note: TP= Total Publications, FAP=First Author Paper; CAP=Corresponding Author Paper; TC= Total Citations, CPP=Citation per Paper.

The author's collaboration network map created through Bibliometrix R tool of the top 20 authors is displayed in Figure 4. Nodes represent the number of publications; the higher the number, the bigger the node size. All these authors spread over 5 clusters with different colours.

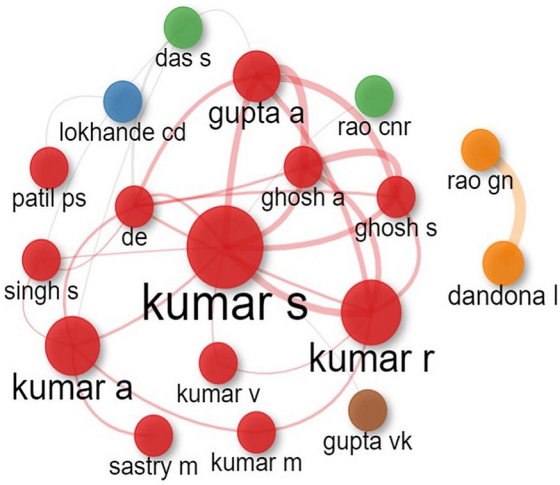


**Figure 4.** Top 20 prolific Authors collaboration network.

## 5.5. Most preferred sources

The 1905 HCPs were published in 546 journals. The distribution of HCPs by reporting journals is widely scattered. The top 20 journals (Table 7) published 15 to 53 papers and together published 500 papers, accounting for 26.25% share in output on Indian optics. Among the top 20 journals, the *Journal of Alloys and Compounds* (n=53) has published the highest number of papers, followed by *Applied Surface Science* (n=37), *Journal of Physical Chemistry C, Sensors and Actuators B-Chemical* (n=34 each), *Journal of Applied Physics* (n=31), etc. *Astronomy & Astrophysics* registered the highest citation per paper (743.2), followed by *Journal of Applied Physics* (244.13), *Materials Chemistry and Physics* (221.85), *Journal of Physical Chemistry B* (217.68), *Biosensors & Bioelectronics* (211.13), and so on. *Astronomy & Astrophysics* registered the highest citation per paper (11148), followed by *Journal of Applied Physics* (7568), *Journal of Alloys and Compounds* (7144), *Journal of Physical Chemistry C* (6138), and *Materials Chemistry and Physics* (5990).

| Journals | TP | TC | CPP | h_index | g_index |
|---|---|---|---|---|---|
| Journal of Alloys and Compounds | 53 | 7144 | 134.79 | 53 | 53 |
| Applied Surface Science | 37 | 5465 | 147.70 | 37 | 37 |
| Journal of Physical Chemistry C | 34 | 6138 | 180.53 | 34 | 34 |
| Sensors and Actuators B-Chemical | 34 | 5905 | 173.68 | 34 | 34 |
| Journal of Applied Physics | 31 | 7568 | 244.13 | 31 | 31 |
| Materials Chemistry and Physics | 27 | 5990 | 221.85 | 27 | 27 |
| Ophthalmology | 25 | 4084 | 163.36 | 25 | 25 |
| Spectrochimica Acta Part A-Molecular and Biomolecular Spectroscopy | 25 | 3382 | 135.28 | 25 | 25 |
| Journal of Geophysical Research-Atmospheres | 24 | 4885 | 203.54 | 24 | 24 |
| Physical Review B | 23 | 4143 | 180.13 | 23 | 23 |
| RSC Advances | 23 | 3514 | 152.78 | 23 | 23 |
| Thin Solid Films | 22 | 4402 | 200.09 | 22 | 22 |
| ACS Applied Materials & Interfaces | 22 | 3339 | 151.77 | 22 | 22 |
| Journal of Physical Chemistry B | 19 | 4136 | 217.68 | 19 | 19 |
| Journal of the American Chemical Society | 19 | 3733 | 196.47 | 19 | 19 |
| Solar Energy Materials and Solar Cells | 19 | 3705 | 195.00 | 19 | 19 |
| Langmuir | 17 | 3424 | 201.41 | 17 | 17 |
| Journal of Crystal Growth | 16 | 2279 | 142.44 | 16 | 16 |
| Astronomy & Astrophysics | 15 | 11148 | 743.20 | 15 | 15 |
| Biosensors & Bioelectronics | 15 | 3167 | 211.13 | 15 | 15 |

**Table 7.** Most preferred sources.
Note: TP=Total Publications; TC=Total Citations; CPP=Citation per Paper.

### 5.6. Most frequently explored topics

Keywords help researchers get an idea about the often-explored topics. The list of keywords that captures the essence of their topical contribution is presented in Table 8. A total of 9625 keywords appeared in 1905 HCPs. Among them, 7310 (76%) keywords occurred once, 1059 (11%) keywords occurred twice, and 415 (4%) keywords occurred thrice. Furthermore, 615 (6%) keywords occurred five or more times, representing the main research stream. Table 8 shows the top 60 significant keywords, with "optical-properties" considered as the most occurred keyword (n=410), followed by "nanoparticles" (n=168), "thin-films" (n=129), "photoluminescence" (n=118), etc.

| Rank | Keyword | Occurrences | TLS | Rank | Keyword | Occurrences | TLS |
|---|---|---|---|---|---|---|---|
| 1 | optical-properties | 410 | 879 | 31 | eye | 26 | 5 |
| 2 | nanoparticles | 168 | 405 | 32 | mechanical-properties | 26 | 19 |
| 3 | thin-films | 129 | 321 | 33 | nanocomposites | 26 | 69 |
| 4 | photoluminescence | 118 | 376 | 34 | photocatalytic activity | 25 | 83 |
| 5 | luminescence | 88 | 248 | 35 | sol-gel | 25 | 66 |
| 6 | nanocrystals | 74 | 213 | 36 | ions | 24 | 52 |
| 7 | absorption | 70 | 139 | 37 | light | 24 | 28 |
| 8 | silver nanoparticles | 62 | 171 | 38 | electronic-structure | 23 | 42 |
| 9 | films | 61 | 105 | 39 | nanowires | 23 | 78 |
| 10 | quantum dots | 61 | 146 | 40 | photocatalysis | 23 | 62 |
| 11 | spectroscopy | 60 | 131 | 41 | titanium-dioxide | 23 | 65 |
| 12 | electrical-properties | 56 | 144 | 42 | zno nanoparticles | 23 | 63 |
| 13 | fabrication | 56 | 141 | 43 | hydrothermal synthesis | 21 | 53 |
| 14 | gold nanoparticles | 56 | 142 | 44 | physical-properties | 21 | 31 |
| 15 | nanostructures | 56 | 179 | 45 | visible-light | 21 | 63 |
| 16 | x-ray diffraction | 50 | 138 | 46 | carbon nanotubes | 20 | 30 |
| 17 | spectra | 47 | 104 | 47 | in-vitro | 20 | 15 |
| 18 | fluorescence | 43 | 115 | 48 | magnetic-properties | 20 | 48 |
| 19 | nanorods | 41 | 115 | 49 | nonlinear-optical-properties | 20 | 14 |
| 20 | zno | 40 | 119 | 50 | electron microscopy | 19 | 66 |
| 21 | sensor | 39 | 56 | 51 | raman-scattering | 19 | 58 |
| 22 | energy-transfer | 38 | 107 | 52 | zinc-oxide films | 18 | 43 |
| 23 | surface-plasmon resonance | 37 | 89 | 53 | in-vivo | 17 | 14 |
| 24 | zinc-oxide | 37 | 132 | 54 | optical absorption | 17 | 50 |
| 25 | semiconductors | 35 | 92 | 55 | enhanced raman-scattering | 16 | 56 |
| 26 | solar-cells | 35 | 75 | 56 | photocatalytic degradation | 16 | 38 |
| 27 | tio2 | 33 | 110 | 57 | spectroscopic properties | 16 | 39 |
| 28 | adsorption | 29 | 78 | 58 | biosensor | 15 | 28 |
| 29 | metal nanoparticles | 29 | 71 | 59 | optical-absorption | 15 | 27 |
| 30 | xrd | 27 | 70 | 60 | raman spectroscopy | 15 | 47 |

**Table 8.** Most occurred significant keywords. Note: TLS= Total Link Strength.

The selection of keywords shows the theme of the research. Figure 5 shows the keyword co-occurrence network visualisation, representing that the keywords were frequently used in these 1905 HCPs. Of the 9625 keywords, 128 meet the threshold minimum of 15 occurrences. 60 keywords out of 128 were chosen for the co-occurrence network. The keyword size shows the frequency of its occurrence, and the network lines show the links between the keywords. These 60 keywords are spread over six clusters; Cluster 1 consists of 18 keywords, Clusters 2, 3, and 4 comprised of 11 keywords each, Cluster 5 consists of 8 keywords and Cluster 6 consists of one keyword. These 60 keywords have 849 links with 2989 total link strength. Table 8, Fig.5 & 6 present the most occurred keywords list with their total link strength and the word cloud map.

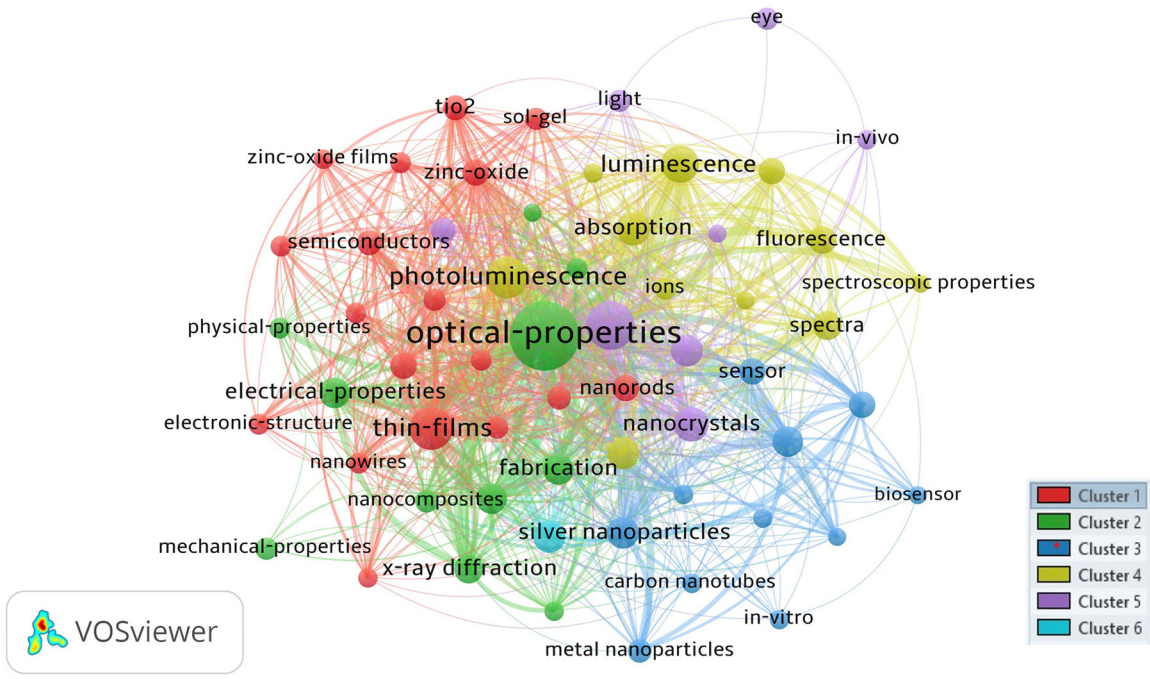


**Figure 5.** Keywords co-occurrence network visualisation.

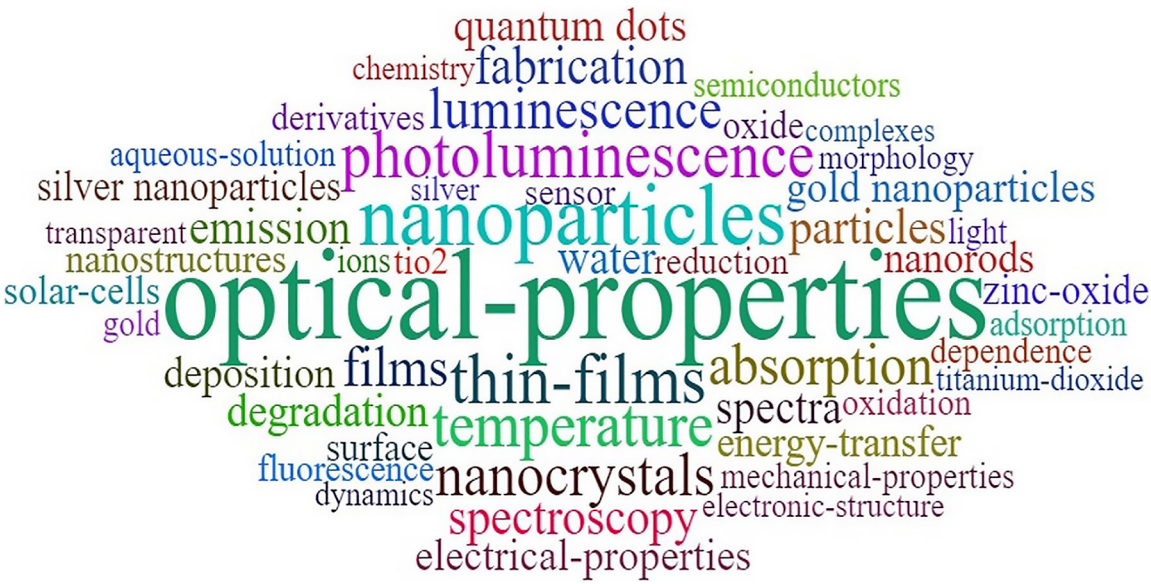


**Figure 6.** Keywords cloud map.

## 6. DISCUSSION AND CONCLUSION

A total of 1905 HCPs were published in 546 journals by authors from 91 countries. The highest number of papers, 122, was published in 2009 and 2014, the highest number of citations, 29807, were counted in 2009, and the most impactful (ACPP=474.08) year was 2003. The highest collaboration was found with the USA (302), Germany (140) and England (126), whereas Switzerland had the highest ACPP (930.36). Institutionally, the top three productive institutes include the Indian Institute of Technology System, India, CSIR India and DST India. The Indian most productive authors in optics are Kumar S (n=33), Kumar A (n=29) of

Guru Nanak Dev University, Amritsar, Kumar R (n=25) of Panjab University, Chandigarh and Kumar V (n=25) of Delhi University, New Delhi contributed 5.88% of total HCPs. The top four most productive journals, such as Journal of Alloys and Compounds, Applied Surface Science, Journal of Physical Chemistry C and Sensors and Actuators B-Chemical published 8.3% of the total HCPs. Highly cited papers were published not only in high-impact factor journals but also in lower-impact factor journals. The most explored topics during the study period were optical properties, nanoparticles, thin films and photoluminescence. The paper by Agostinelli *et al.* in 2003 ranked first by citation indicator of total citations since publication to the end of 2021. The paper by Aghanim *et al.* in 2020 had the highest citations in 2021. The highly cited papers would not always have high strength or visibility in research society. The history of a paper's citations with time is needed to understand the impact of highly cited papers. The citation history shows characteristics of a paper's influence after its publication. Citation history and citations in the most recent year should be considered to evaluate the impact of a paper.

The HCP's productivity in optics research by India is still not as high as expected since few authors contributed only one paper at a time during the study period of 30 years. Furthermore, the country has not shown promising progress in its growth rate of the production of HCPs over time. However, from 2006 to 2014, HCP's productivity was progressive. The low growth rate of high-quality publications in optics shows a lack of high-quality scientists/ institutions in the country; it is a matter of caution. Most of the high-quality research output in India results from some academic institutions working in isolation and not in collaboration. Collaboration among institutional research in optics is limited to a few highly cited papers. The challenge facing the nation's top scientists is how to encourage multi-institutional collaboration/research to produce and publish high-quality, high-impact research in optics.

## Conflict of interest

The authors declare that there is no conflict of interest.

## Statement of data consent

The data generated during the development of this study was included in the article. ●

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