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Research Contribution and Impact of Indian Institutes of Science Education and Research (IISERs) to Physical Sciences

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The present study explores the research contribution of five selected Indian Institutes of Science Education and Research (IISERs) in the discipline of physical sciences over the last 15 years period, 2006-2020. The selected five IISERs published a total of 3,354 research articles which comprise 47.34% share of internationally co-authored articles. The publications are interpreted in terms of chronological growth, collaboration trend, focus sub-areas, scholarly communication channels, leading collaborating countries, keywords and citation impact. Among the selected IISERs, IISER-P followed by IISER-K and IISER-M were the major producers of research papers. Since 2016, a sharp rising trend in terms of publication output and international collaborative efforts was observed. Furthermore, the collaboration trend also witnessedthat there were a strong international collaboration linkages among IISERS and developed countries like the USA, Germany and Italy were the primary collaborating countries.In addition, the international experimental research consortia like CMS, LIGO, VIRGO and BELLE Collaboration played a crucial role in global cooperative research efforts of IISERs.

Keywords: *Scientometrics; Indian Institutes of Science Education and Research; IISER; Physical Sciences; Research*

1 INTRODUCTION

During the pre and post-independence era, Indian scientists contribution to world scientific research were outstandingand some of the pioneer Indian

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scientists who was born in the 19th century like J.C. Bose (1858-1937), C.V. Raman (1888-1970), M.N.Saha (1893-1956), S.N. Bose (1894-1974), K.S.Krishnan (1898-1961) and Kulesh C. Kar (1899-1975) gained international prominence through their exceptional landmark contribution[1-2]. They have also built up world-class scientific institutions to attain scientific culture among Indians with little support from the Government of the day. Later on, during the 20th century, a lot of Indian scientists continued this research legacy and also played their significant parts in building post-independence Science & Technology infrastructure and in the formulation of India's science policies. This traditional history and rich legacy helped India to gain research excellence in scientific research at the highest level.India's science and technology (S&T) research trendalso addressedthe fact[3]thatIndia's publication growth in terms of global share is remarkable in physics domain and it has improved its position gradually from 10th rank in 2009 to 6th rank in 2014. Additionally, materials science and condensed matter physics were among the most prominent areas of research as well[4-5].

Meanwhile, India maintains a strong infrastructural base for physics research and its top elite institutions are competitive with those in Europe, the USA and Asia, and considers among the world's top ranks as well[6]. Nearly 435 institutions from the academic as well as research sector are involved with physics research in India[7]. Of these, the Indian Institutes of Science Education and Research (IISERs) are among the premier Indian institutions devoted to research and education in the basic sciences with state-of-the-art facilities. The pioneer five IISERs were founded as autonomous institutions under the Ministry of Human Resource Development, India in between 2006 and 2008[8]. In 2012, the institute was declared as Institutes of National Importance by an Act of Parliament[9]. Subsequently, two new IISERs were set up in Tirupati (2015) and in Berhampur (2016) as well[10]. In terms of producing significant research growth in high-quality science, the group of IISERs secured 24th position among the top 100 global rising institutions[11]. Further, the established five IISERs were considered among the top 175 young universities[12]. So, within a short period of time, the institutes achieved significant milestonesand recognition. Therefore, the present scientometric observation zooms on the research trend and impact of selected IISERs in the field of physical sciences.

2 LITERATURE REVIEW

Literature review explores India's status in physical sciences research as well as group of IISER's contribution to scientific research.For instance, assessment of India's science and technology (S&T)publications[4,13]narrated that chemistry and physics were the predominant areas of research.Quality research in physics was still restricted to a few institutions of India whereas industries' role in India's scientific research was almost absent. Additionally,

Maharashtra, West Bengal, Karnataka and Delhi were the leading Indian states in terms of producing research papers in physics[5,7].

On the contrary, Indian research trend in materials science[14] during 2001-2010showed that India ranked 8th among the top 20 countries in materials science research, with its global publication share of 3.87%. Indian scientists produced 20.22% publications through international collaborative efforts where the United States, Germany and Japan were the leading partnering countries. In another two studies on India's research on nanotechnology[15]and nuclear science[16] depicted that India occupied 3rd and 7th rank among leading countries by sharing 7.60% and 2.34% contribution of world publications. Alternatively, Indian authorship trend in selected Physical Review journals of American Physical Society[17]pointed out that Physical Review-D followed by Physical Review-B journal were the most preferred journals among Indian physicists. Tata Institute of Fundamental Research Mumbai (TIFR), Bhabha Atomic Research Centre Mumbai (BARC) and Saha Institute of Nuclear Physics Kolkata (SINP) were the most prolific Indian institutions.

Alternatively, a few scientometric studies have been carried out to gauze the performances of IISERs' in scientific research. Five IISERs produced total 2,542 publications comprising 30.80% share of international collaborative output. Further, chemistry and physics were the emphasized areas of research among the scientists of IISERs. In terms of research productivity – impact, IISER Kolkata was the most prominent among group of IISERs followed by IISER Pune and IISER-Mohali[18,19].The trend of basic sciences research in IISERs from 2015 to 2019 as reflected in the Scopus database[20] revealed that the IISERs contributed 7,329 research publications which accounted 1.90% share of Indian basic sciences research output. Physics and Astronomy was the most focused research area with 22.6% publications followed by Chemistry with 20.1% publications. Besides, Springer Nature and Royal Society of Chemistry were the leading publishers for publishing research results. In another attempt, the research contribution of five IISERs from 2006 to 2020 depicted[21] that the faculty members produced 10,494 journal articles. A strong domestic collaboration network (61.51%) has been found along with apparent international linkages (35.1%).Thecollaboration scenario demands more inter-level collaboration among IISERs.

The present review addresses that every year Indian physicists contributed a significant proportion of research output in world S&T literature and since inception, the group of IISERs also produced quality research output collaborating with domestic as well as international partners. A few effortshave already been made to outline the research competitiveness of group of IISERs. Furthermore, physics was found as one of the preferred areas of research[18, 21]. But, no such attempt has yet to find on the research performance of the group of IISERs to physical sciences discipline. Hence, this study fills this research

gap by examining the research outputs of five established IISERs in the field of Physics over the past 15 years.

3 OBJECTIVES OF THE STUDY

The present study addresses the scholarly publication behavior of the faculty members of the group of IISERs in the field of physical sciences over the past 15 years period. The objectives are to:

i. find out research contribution and collaboration trend of IISERs in physics,
ii. reveal prominent sub-areas of physics research,
iii. identify popular scholarly communication channels and leading collaborating countries,
iv. examine strong citation burst references and frequently used keywords,
v. report scholarly citation impact

4 DATA SOURCE, LIMITATIONS AND METHODOLOGY

The present study analysed the research articles output of the faculty members of five establishedIndian Institutes of Science Education and Research (IISERs) in the area of Physical Sciences over last 15 years period, 2006-2020. The five IISERs are IISER Kolkata (IISER-K), IISER Pune (IISER-P), IISER Mohali (IISER-M), IISER Bhopal (IISER-B) and IISER Thiruvananthapuram (IISER-TVM). According to the Nature Index-2021, these IISERs have also been ranked 10, 13, 28, 19 and 26 positions respectively among Indian academic institutions in Physical Sciences research[22].The other two IISERs i.e. IISER Tirupati and IISER Berhampur are in the early days of development. Therefore, these two newly founded IISERs have been excluded from the study.

For this purpose, the Web of Science (WoS) - core collection citation database (www.webofknowledge.com) of *Clarivate Analytics* was consulted during the 1st and 2nd week of August, 2021. The full record of research articles of individual IISER as well as group of IISERs were searched using '*Affiliation*' field tag and then the results were refined further implementing the following strategies:

Document Types: Articles

Research Areas: Physics

Timespan: 2006-2020

The search query showed total 3,424 records includingarticles (3354), review (28), proceedings paper (27), corrections (24), editorial materials (14), letters (3), book chapters (2) and news items (1). Of these, only journal articles

(3,354) were selected and exported in three different formats i.e. excel, plain text and tab-delimited (win) for further analysis to get desired output as specified in the objectives of the study. Additionally, the Biblioshiny webinterface of Bibliometrix package of R software, CiteSpaceSoftware and VOSviewer software tools have also been used for mapping the research pattern. Here, different scientometric indicators like ACPP, h-index[23], g-index[24], hg-index[25], A-index[23],*p*-index[26], highly cited and uncited papers have been applied for assessing the scholarly citation impact.

5 RESULTS

The retrieved records have been categorized and interpreted using tables and figures in the following sub-sections:

5.1 SCIENTIFIC RESEARCH CONTRIBUTION OF IISERS

Table-1 examines the data related to research output, most productive area and corresponding IISER contribution to the area of physical sciences. Chemistry was the most emphasize research area in all the IISERs except IISER-P where physics was the top priority field. Out of five IISERs, the faculty members of IISER-P contributed 1,278 articles which registered 39.7% share of its total research output. This is followed by IISER-TVM and IISER-M having 35.88% and 33.31% sharesof their total articles respectively. Apart from these, IISER-TVM and IISER-K attracted higher average citations as compared to their total research impact. Overall, the group of IISERs produced total 3,354 articles which comprised 31.94% of their total research output in the field of physical sciences.

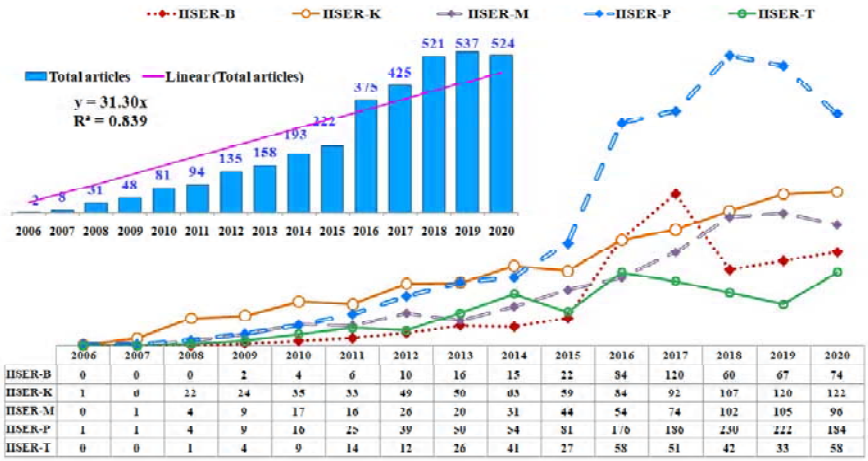
Table 1: Research status of five selected IISERs during 2006-2020

IISERs	Total Research Articles	ACPP	Most productive area	Research output in Physics by IISERs		
				No. of Articles	%	ACPP
IISER-B	1,776	16.52	Chemistry	480	27.03%	16.2
IISER-K	3,025	23.68	Chemistry	867	28.66%	37.65
IISER-M	1,798	14.02	Chemistry	599	33.31%	13.87
IISER-P	3,220	19.26	Physics	1,278	39.7%	18.46
IISER-TVM	1,048	41.2	Chemistry	376	35.88%	67.9
Total =	10,499	18.70	Chemistry	3,354	31.94%	21.4

ACPP= Average citations per paper

5.2 CHRONOLOGICAL DISTRIBUTION OF RESEARCH ARTICLES

Figure-1 illustrates the distribution of research articles over the last 15 years period. Out of total 3,354 research articles of five IISERs, IISER-Pcontributed the largest number of 1,278 research articles (38.10%) followed by IISER-K having867 articles (25.85%). Alternatively, IISER- TVM produced minimum 376 articles (11.21%). The research journey of IISERs began with 2 articles in 2006 while a majority of articles were published in the year 2019 with 537 articles followed by the year 2020 with 524 articles. From the year 2016 onwards, a positive sharp rising growth has been seen and the value of *R*- squared (R^2 = 0.839) on the figure-1 also confirmed the fact that a lineargrowth trend has been evidenced in the scientific research. Here, some articles may appear in more than one IISER category on account of their inter-institutional level collaboration.



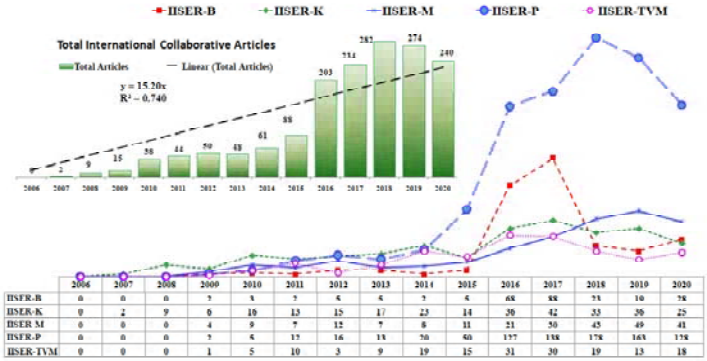
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
IISER-B	0	0	0	2	4	6	10	16	15	22	84	120	60	67	74
IISER-K	1	0	22	24	35	33	49	50	63	59	84	92	107	120	122
IISER-M	0	1	4	9	17	16	26	20	31	44	54	74	102	105	90
IISER-P	1	1	4	9	10	25	39	50	94	81	170	130	230	222	134
IISER-T	0	0	1	4	9	14	12	26	41	27	58	51	42	33	58

Figure-1: Growth of research output of selected IISERs by years

5.3 YEAR WISE DISTRIBUTION OF INTERNATIONALLY COLLABORATIVE OUTPUT

Figure-2 demonstrates the distribution of internationally collaborative articles of selected IISERs by years. During the study period, the faculty members of selected IISERs produced a total of 1,588 internationally co-authored research articles which accounted 47.35% share of the total articles.Of these, IISER-P contributed the highest number of 852 articles (53.65%) followed by IISER-K with 287 articles (18.07%) whereas IISER-T produced minimum 173 articles (10.9%). In 2006, the international collaborative efforts began with just 2 articles by the scientists of IISER-K.Later, from the year 2016 onwards, a sharp rise has been witnessed in the international collaborative output and the value of *R*-squared (R^2= 0.740) on the figure-2 also confirmed

that a linear trend has been noticed in the international collaborative research efforts. Here, some articles may count in more than one IISER due to their inter-institutional level collaboration.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
IISER-B	0	0	0	2	3	2	4	4	2	4	68	88	73	10	28
IISER-K	0	2	9	0	10	13	15	17	23	14	30	42	33	30	25
IISER M	0	0	0	4	9	7	12	7	6	11	21	50	45	49	41
IISER-P	0	0	0	2	4	12	16	18	28	40	137	198	178	168	178
IISER-TVM	0	0	0	1	5	10	3	9	19	15	31	30	19	13	18

Figure 2: Growth of international collaborative articles of selected IISERs by years

5.4 INTER- IISERS COLLABORATION

Table-2 delineatesthe data related to inter-collaboration in research among the five IISERs in the field of physical sciences. Of these, IISER-P contributed a majority of 170 papers collaborating with other IISERs followed by IISER-B with 157 articles. On the contrary, IISER-M had weaker collaboration linkage with other IISERs. Alternatively, the strongest research collaboration network was apparent between IISER-P and IISER-B comprising 148 articles. This is followed by IISER-K and IISER-T having 64 collaborated articles. Here, the possible reason may be that IISER-P and IISER-B were the institutional members of CMS collaboration while IISER-K and IISER-TVM have common memberships under LIGO-VIRGO scientific collaborations. These international scientific collaboration groups play a prominent role in inter-IISERs collaboration as well as international collaborative researchin the domain of physical sciences.

Table 2: Inter-level research collaboration among the selected IISERs

IISER	IISER-B	IISER-K	IISER-M	IISER-P	IISER-T
IISER-B	--	2	6	148	1
IISER-K	2	--	3	6	64
IISER-M	6	3	--	9	0
IISER-P	148	6	9	--	7
IISER-T	1	64	0	7	--
Total=	157	75	18	170	72

5.5 RESEARCH EMPHASIS AREAS IN PHYSICAL SCIENCES

Figure-3 demonstrates the research focus areas of selected IISERs in the field of physical sciences. In the case of four selected IISERS i.e. IISER-B, IISER-K, IISER-P and IISER-T, '*Physics Particles Fields*' was the most productive research area while the scientists of IISER-M preferred to '*Physics Atomic Molecular Chemical*' field. Overall, '*Physics Particles Fields*' was the most emphasis research area having1,092 articles(32.56%) followed by '*Physics Atomic Molecular Chemical*' with 665 articles(19.83%) and '*Physics Applied*' having 635 articles (18.93%). Conversely, sub-fields such as, '*Nanoscience Nanotechnology*', '*Fluids andPlasmas*''*Mechanics*', '*Spectroscopy*', '*Polymer Science*' and '*Optics*' were the lesser emphasized areas for conducting research activities.

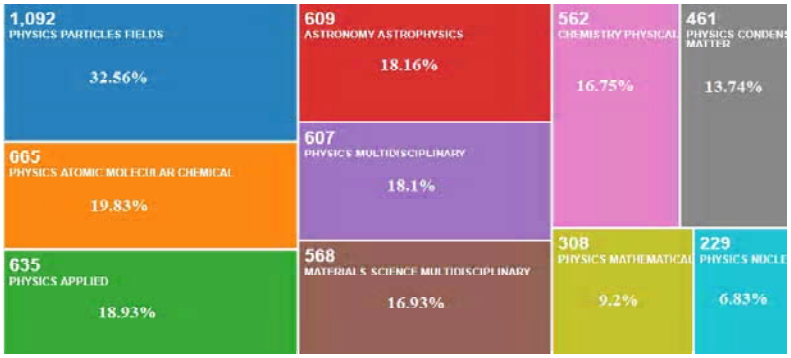


Figure 3: Distribution of research focus areas according to WoS categories

5.6 SCATTERING OF JOURNALS AND ARTICLES FOR PUBLICATION OF RESEARCH RESULTS

Table-3 determines the data related to the scattering of journals and articles according to impact factor (IF). The faculty members of IISER-K used a maximum of 126 journals having average articles of 6.88 per journal for publishing their research results whereas IISER-T preferredtheleast number of 80 journals having 4.7 average articles per journal. Overall, the faculty members of the group of IISERs considered 197 journals having 17.02 average articles per journal for dissemination of research results.

Apart from these, IISER-T shared the highest proportion of 17.02% articles to very highIF journals (6> -) while IISER-P contributed its maximum share of 53.3%articles to high IF journals. Alternatively, IISER-K published largest share of 15.34% and 52.02% articles to low and moderate IF journals respectively. Overall, the selected IISERs published only 10% articles to low IF journals while 11.8% articles were appeared in the very high IF journals (6>). It is significant to argue from the dataset that about half of the total articles (48.1%) were published in high impact journals having more than 4

IF. In IF wise distribution of articles, one article may count in more than one IISER category for their inter-institutional level collaboration.

Table 3: Scattering of journals and articles according to IF

IISERs	Total Journals	Avg. articles per journal	Impact Factor (JCR, 2021) wise distribution of articles with share			
			Low IF - ≤2	Moderate IF 2>- ≤4	High IF 4> - ≤6	Very High IF 6>-
IISER-B (N=480)	83	5.78	32 (6.67%)	178 (37.0%)	229 (47.71%)	41 (8.54%)
IISER-K (N=867)	126	6.88	133 (15.34%)	451 (52.02%)	197 (22.72%)	86 (9.92%)
IISER-M (N=599)	95	6.30	70 (11.7%)	288 (48.1%)	166 (27.71%)	75 (12.52%)
IISER-P (N=1278)	102	12.53	68 (5.32%)	362 (28.32%)	681 (53.3%)	167 (13.1%)
IISER-T (N=376)	80	4.7	37 (9.84%)	160 (42.55%)	115 (30.6%)	64 (17.02%)
Total= (N=3354)	197	17.02	335 (10%)	1406 (42%)	1217 (36.3%)	396 (11.8%)

5.7 MOST POPULAR JOURNALS USED FOR PUBLISHING RESEARCH RESULTS

Table-4 exhibits the most popular journals among the faculty members of IISERs for the dissemination of research results. In case of the scientists of IISER-K, IISER-M and IISER-T, Physical Review-D journal published maximum articles of 97, 85 and 56 articles respectively. Additionally, Journal of High Energy Physics was the preferred journal among the scientists of IISER-B and IISER-P with 64 and 270 articles respectively. Overall, Physical Review-D journal published a majority of 331 articles followed by Journal of High Energy Physics with 308 articles and Physical Review-B with 199 articles. Conversely, 152 articles of Physical Review Letters journal received wider citations impact with the highest 149.57 average citations per paper and *h*-index score of 44. In terms of *p*-index score, Physical Review Letters received a maximum score of 150.37 followed by Physics Letters B with 48.12. It is significant to note that the leading 5 scholarly journals contain1,147 articles (34.2%) which form the core nucleus zone. Furthermore, American Physical Society (967), Springer Nature (627), Elsevier (518) and IOP Publishing Ltd (311) were the leading preferred publishers among the IISERs' physicists.

The composite performance index (*p*-index or mock *h*-index) was formulated by Prathap[26]and can be calculated as follows:

p-index = $\left(C.\frac{c}{p}\right)^{\frac{1}{3}}$ Where, C= total number of citations; P= total number of papers

Table 4: Most productive journals of research communication

Name of the Journal and IF	IISER-B	IISER-K	IISER-M	IISER-P	IISER-T	Total Papers (P)	TC (C)	ACPP	h-index	*p-index*
Physical Review D	36	**97**	**85**	109	**56**	**331**	*5,746*	*17.36*	*38*	46.38
Journal of High Energy Physics	**64**	8	13	**270**	7	308	*5,123*	*16.63*	*35*	44
Physical Review B	48	29	38	56	32	199	*2,725*	*13.69*	*27*	33.41
Physics Letters B	37	15	5	134	0	157	*4,182*	*26.64*	*36*	48.12
Physical Review Letters	15	39	30	78	18	152	***22,735***	***149.57***	***44***	**150.37**
Physical Review A	12	47	40	34	8	139	*1,619*	*11.65*	*19*	26.62
European Physical Journal C	32	25	9	91	3	134	*3,277*	*24.46*	*28*	43.11
Physical Chemistry Chemical Physics	19	28	11	34	22	114	*1,634*	*14.33*	*19*	28.61
Physical Review E	11	23	32	37	11	114	*1,520*	*13.33*	*21*	27.26
Journal of Chemical Physics	6	29	20	24	8	87	*702*	*8.07*	16	17.83
Journal of Physical Chemistry A	3	16	22	17	12	70	*994*	*14.2*	18	24.17
Journal of Physical Chemistry Letters	7	9	6	28	18	67	*1,903*	*28.4*	*22*	37.81
Journal of Physics Condensed Matter	12	16	14	20	7	63	*318*	*5.05*	9	11.71
Journal of Applied Physics	14	15	7	14	11	60	*437*	*7.28*	11	14.71
Applied Physics Letters	13	14	16	13	3	58	*711*	*12.26*	*15*	20.6

TC= Total Cited; ACPP= Average citations per paper

5.8 COUNTRY-WISE DISTRIBUTION OF COLLABORATION OUTPUT

Table-5 shows the data related to leading collaborating countries and corresponding citations impact. Out of total 85 countries, the USA producedthe highest number of 996 co-authorship articles which received a maximum *h*-index score of 76 as well. This is closely followed by Germany having 951 articles and Italy having 810 articles. Alternatively, the co-authorship papers with Taiwan attracted a maximum of 53.99 average citations per paper while South Korea received the highest *p*-index score 130.47. Figure-4 visualizes the research collaboration linkage of leading 20 countries with India (IISERs). Out of 2 clusters, one cluster contains 12 countries (Australia, Germany, Italy, Japan, Peoples R. China, Poland, Russia, South Korea, Spain, Switzerland, Taiwan and USA) whereas another cluster contains 8 countries (Brazil, Canada, England, France, Hungary, Netherlands, Scotland and Wales).

Table 5: Country-wise collaboration output of IISERs' scientists

Country/ region	IISER-B	IISER-K	IISER-M	IISER-P	IISER-TVM	Total Papers (P)	TC (C)	ACPP	*h*-index	*p*-index
USA	160	**149**	**133**	**655**	**103**	**996**	**46,334**	46.52	**76**	129.17
Germany	153	123	129	647	99	951	45,590	47.94	75	129.77
Italy	142	98	87	608	74	810	41,330	51.02	70	128.23
Peoples R. China	143	96	84	595	70	788	41,327	52.45	70	129.42
England	**166**	92	31	613	81	781	41,579	53.24	71	130.33
South Korea	142	85	83	597	65	774	41,462	53.57	71	**130.47**
Spain	145	89	79	591	67	773	41,031	53.08	70	129.62
France	142	93	55	608	69	772	40,081	51.92	70	127.67
Russia	137	90	77	587	68	761	40,770	53.57	70	129.74
Taiwan	137	83	80	586	67	755	40,765	**53.99**	70	130.1

TC= Total Cited; ACPP= Average citations per paper

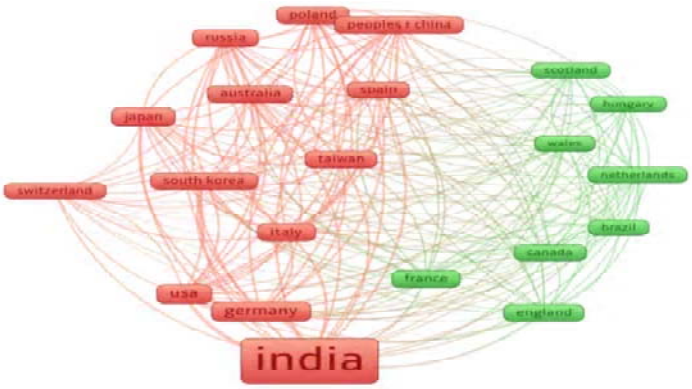


Figure 4: Collaboration network of leading 20 countries with India (IISERs)

5.9 REFERENCES WITH STRONG CITATION BURST (2006-2020)

Figure-5 determines the leading references that have the strongest citation bursts from 2006 to 2020 in the area of physical sciences. A citation bursts indicates that the scientific community has paid special attention towards the underlying contribution[27]. Here, the last column indicates a line representing the period, in which thered line means the time period of citation bursts.The first burst article was 'CMS Collaboration Report'[28]published in the year 2010with a maximumstrength of 36.18, followed bythe paper of Sjostrand, Mrenna&Skands in 2006[29]with burst strength of 27.13. It is significant to note that the oldest paper byBoys &Bernardi in 1970[30]also received burst strength of 14.58 and occupied 13 ranks. Maximum papers started to burst in the year 2015.

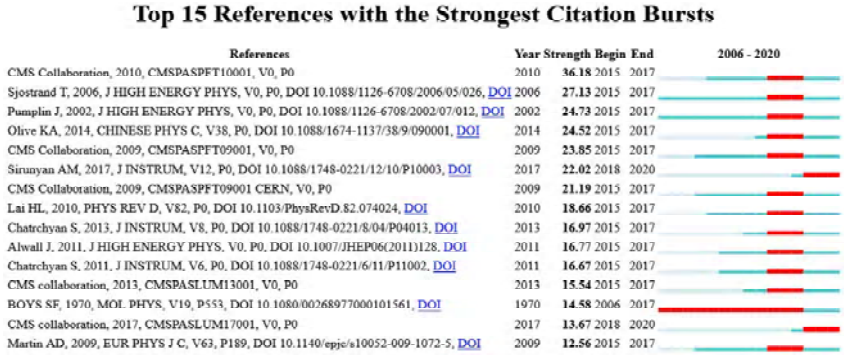


Figure 5: Top 15 references with the strongest citation bursts

5.10 RESEARCH TRENDS AS REFLECTED IN KEYWORDS

Figure-6depicts the popular as well as trending topics based on the authors' keywords. Out of 3,009 author keywords, '*hadron-hadron scattering (experiments)*' occurred highest 187 times (20%) followed by '*cms*' with 127 times (14%), '*physics*' with 100 times (11%), '*beyond standard model*' with 80 times (9%) and '*supersymmetry*' with 60 times (6%). It is evident from the figure shows that '*ibm quantum experience*' was the trending topic in 2020 followed by '*hadron-hadron scattering (experiments)*' and '*cms*'.

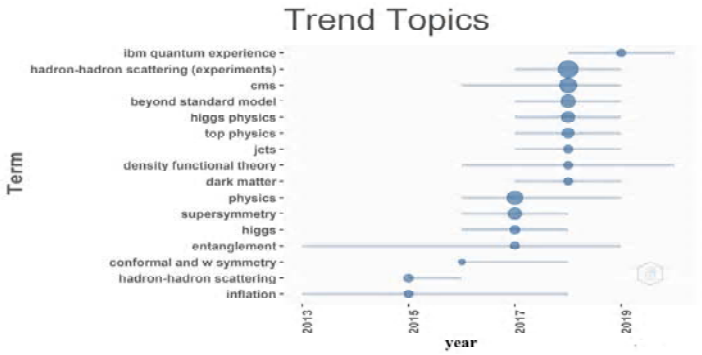


Figure6: Trend topics by years

5.11 CITATION REPORT

Table-6illustrates the data related to different indicators and corresponding IISER's score. The publications of IISER-T attracted the highest average of 67.9 citations per paper followed by IISER-K with 37.65. Furthermore, the publications of IISER-T gained outstanding performance scores in terms of *g*-index, *hg*-index, *A*-index and *p*-index. Alternatively, maximum 29 papers of IISER-K received at least 100 or more citations while 8.76% articles of IISER-K still remain uncited. Overall 3,354 articles received average citations of 21.4 per paper anda total of 73 articles cited at least 100 or more times. Besides, 8.17% articles of the group of IISERsstill remain uncited.

Here,*hg*- index is the combined indicator[25]which uses the properties of both the indexes and can be determined by using the following formula:

$$hg = \sqrt{h \times g}$$

Here, *A*-index[23] also indicates the average number of citations of articles included in the *h*-core. Mathematically, this can be expressed by using the following formula:

$$A = \frac{1}{h}\sum_{j=1}^{h} cit_j$$

Table 6: Scholarly impact of the research articles of IISERs in physical Sciences

Indicators	IISER-B	IISER-K	IISER-M	IISER-P	IISER-T	Total
Total Publications	480	867	599	**1,278**	376	3,354
TC	7,778	32,639	8,310	23,590	**25,532**	71,775
ACPP	16.2	37.65	13.87	18.46	**67.9**	21.4
h-index	42	53	38	**63**	51	88
g-index	68	49	68	103	**157**	201
hg-index	53.44	51	50.83	80.55	**89.5**	133
A-index	89.5	464.8	97.47	135.52	**851.92**	380.43
p-index	50.13	107.11	48.66	75.8	**120.13**	115.38
AC_{100}	7	**29**	10	25	24	73
%uncited	8.75%	**8.76%**	7.84%	6.65%	8.51%	8.17%

TC= Total times cited; ACPP= Average citations per paper; AC_{100}= Articles that received at least 100 or more citations

6 CONCLUSION

In the last 15 years period, physical sciences were found to be the second priority research area of the faculty members of IISERs only behind chemical sciences. The five selected IISERs publisheda total of 3,354 research articleswhich comprise47.34% share of internationally co-authored articles. Among IISERs, IISER-P and IISER-K were prominent in terms of producing research articles. Overall, a sharp rising trend has been evidencedsince 2016 in terms of publication output and international collaborative efforts. The collaboration trend indicates that a strong international collaboration network has been prominent along with an apparent linkage with the domestic institutions. However, a weaker research association has been witnessed among the IISERs. In this context, it is worth noting that the branches of IISERs should come forward to set up a research consortium by sharing infrastructure, cost and expertise in order to fulfill mutual interest and developmental objectives.

It is also interesting to observe that the publications of IISER-TVM attracted the largest scholarly impact though the output is still very low compared to other IISERs. Alternatively IISER-K, IISER-P and IISER-T produced maximum highly cited papers. Developed countries like the USA, Germany, Italy, Peoples R. China and England were the leading collaborating partners. Among sub-areas of physics, '*Physics Particles Fields*' followed by '*Physics Atomic*

Molecular Chemical' and '*Physics Applied*' were the emphasized research areas of the IISERs. This fact also differ from the earlier result[5]that the condensed matter physics were considered the high productivity sub-fields in Indian physics domain. Alternatively, it is found that '*ibm quantum experience*', '*hadron-hadron scattering (experiments)*', '*cms*' and '*beyond standard model*' were the trending topics. Furthermore, the faculty members of IISERs were highly selective in publishing research results and also published about half of the total articles in high IF journals which also opposed the earlier finding[7] that the Indian physicists published their maximum output in low impact journals. Besides, American Physical Society, Springer Nature and Elsevier were found to bethe most preferred publishers.

In the end, it is noteworthy to address that the physicists of IISERS produced significant contributions in high-energy physics through participating in collaborative research under the international experimental research consortia[17]like CMS, LIGO, VIRGO and BELLE Collaboration. Here,IISERPune and IISERBhopal participated in the CMS experimental collaboration[31]whereas IISER Kolkata and IISER Thiruvananthapuram were joined with the LIGO-VIRGO scientific collaborations[32].Alternatively, IISERMohali was also attachedwith the BELLE Collaboration[33] to team up in high-energy experiments. Through this international experimental consortia initiative, institutional scientists can participate in global level scientific research projects for sharing funds, infrastructure and expertise[17].Hope, in the event of 15 years completion, the insight of the study will be helpful for authorities/ funding agencies in identifying where the groups of IISERs stand in physical sciences research in comparison with other esteemed conglomerate institutes of Indialike IITs, CSIRs, DSTs and DAEs etc.

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