Compatibility-Management between Innovation and Earning: Business Management of Cutting-Edge Photonics Company, Contributing to Three Nobel Prize Wins

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***Abstract*--Hamamatsu Photonics, an excellent Japanese photonics company which started-up in phototubes business as their original vocation indispensable for light detection (HQ; Hamamatsu city, Shizuoka prefecture Japan) and has been growing while keeping high compatibility between innovations and earnings, so as to having contributed to Nobel Prize wins.**

We investigated the reason why they can effectively balance both innovations and earnings while consistently pursuing the unexplored dreams of photonics through top interviews etc. and as a result, we found that the corporate management systems have been built in a cross sectoral manner such as (1) unique SECI model like in-company knowledge circulation system, (2) open innovation practice system enhancing research and development covering very wide industrial areas around their core technologies, (3) on-site compatibility management between dreams (pursuit of the unknown and the yet-undiscovered) and wallet (earning and expense) , (4) autonomous-decentralized management system to meet their customers' needs agilely and flexibly and (5) non-achievement-based human resource cultivation system to encourage self-motivated challenges.

I. INTRODUCTION

According to the recent progress in economic globalization, many Japanese industries, in particular the electronics industries are encountering a serious business environment and gradually losing global share due to Asian emerging countries' power [1]~[5].

However, over-viewing the business areas on photonics, there is a company steadily developing business performance. It is Hamamatsu Photonics K.K. (hereafter abbreviated as "HP") established in 1953.

The outline of the corporate profile is shown in Table 1. HP started its business in 1948 as the name of Tokai Electronics Laboratory by Mr. Heihachiro Horiuchi, a student of Prof. Dr. Kenjiro Takayanagi (now deceased, so called the godfather of television in Japan, honorary professor. Shizuoka University). He inherited Professor Takayanagi's spirit of challenging anything unknown and yet-undiscovered towards the world's top photonics technologies.

The capital is about 35 billion Yen, Number of employees; about 3,200, the president; Mr.Akira Hiruma, their major products; photomultiplier tubes, imaging equipment devices, light sources, opto-semiconductors, imaging and measurement instrument. The net sales (consolidated base) are about 120 billion Yen (September 2014) and the operating profit rate is about 20%.

They expanded their business to the point that the companies' shares were traded on the first section, TSE (Tokyo Stock Exchange) market in 1998.

Putting their core vocation on phototubes they had expanded their business to a wide variety of photonics products, as shown in table 1.

Their photomultiplier tubes occupy a tremendously large world share of approximately 90%. They have been challenging academic areas in addition to industrial areas as well, and succeeding in cutting edge product developments one after another for example 20 inch diameter photomultiplier tube arrays installed in Super-Kamiokande neutrino observation center (constructed in an abandoned mine, in Gifu prefecture Japan in 1996) , which contributed to Nobel Prize wins.

This paper reviews their footsteps and analyzes their business operations under unique technology management from the viewpoints of entrepreneur/engineering[6] and search for a possible guiding orientation to reactivate the manufacturing industries in advanced countries.

TABLE 1 CORPORATE PROFILE SOURCE; HP 2014 ANNUAL REPORT

Company Name	Hamamatsu Photonics K.K.
Established	1953
Capital	about 35,000 Million Yen
Number of Employees	about 3,200
Board of Directors (As of 2015)	
Chairman of the Board	Teruo Hiruma
President and CEO	Akira Hiruma
Main Product Lines	Photomultiplier tubes, Imaging equipment, Light sources, Opt- semiconductors, Imaging and measurement systems
Net Sales (consolidated basis)	about 120,000 Million Yen for the fiscal 2015
Listing First Section of the Tokyo Stock Exchange since 1998	

II. COMPANY HISTORY OF HAMAMATSU PHOTONICS

HP has its headquarters (HQ) and most of its factories in Hamamatsu-city Shizuoka prefecture Japan, or the business startup site, and now headed by Mr A. Hiruma, the third president.

The company history is summarized in Table 2. The company presidency was succeeded from Mr.Horiuchi, the founder to Mr. Teruo Hiruma, the second president in 1978 and then to Mr.Akira Hiruma, the third president in 2009 until the present day. Their typical technological innovations achieved are the contributions to three Nobel Prize wins awarded by the success in the detection of Higgs boson and neutrinos by using HP's latest detection systems facilitated with huge diameter (20 inch) phototube arrays etc.

They have been focusing their major businesses only on

photonics industries while waving the banner of the company slogan "tackling unknown and yet-undiscovered photonics full of mysteries ", as typified by whether light is wave or particle, while setting the company mission of "photon is our business".

The trend of the sales amount and the ordinal profit is shown in Fig.1 and the annual sales breakdown in fiscal 2014 is shown in Fig.2. It is composed of four major business areas as follows, (1) photomultiplier tubes, (2) imaging equipment and light sources, (3) opt-semiconductors, (4) imaging and measurement instruments.

All of them are rooted in their startup business or phototubes. Annual sales are now approaching 120 billion Yen as shown in Fig.1 and still growing. The particularly notable fact is that it keeps high operating income rate reaching about 20 % in spite of R&D oriented enterprise.

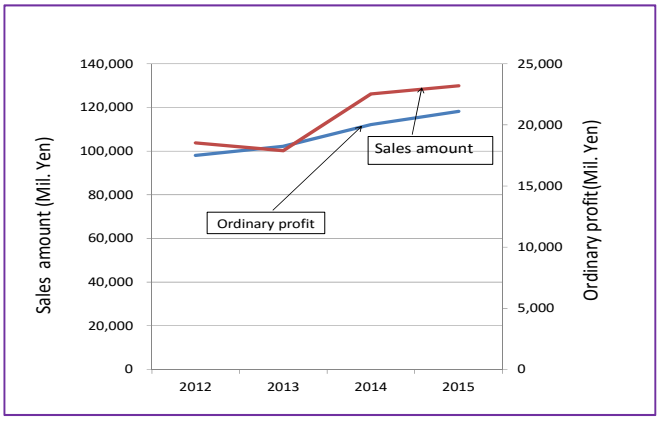

Fig.1 Trend of the sales amount and the ordinal profit (Source: HP 2014 annual report)

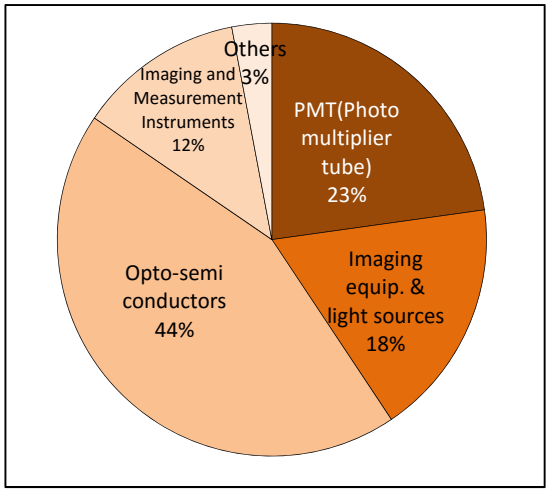

Fig.2 Annual sales breakdown Source HP 2014 annual repot

III. PREVIOUS STUDIES ON HP

The previous studies were surveyed on the data basis of CiNii (Scholarly and Academic Information Navigator) of National Institute of Informatics. Technical papers authored by HP engineers have been consistently increased, however, business economics related papers published before 1990 were hardly found and the issued ones after 1990 were reviewed.

Surveyed papers are classified into four areas such as (1) corporate mission and management policy, (2) industry-academia collaboration, (3) business management, (4) local culture analysis affected on the innovative background. Outlines of them are summarized below.

TABLE 2 COMPANY HISTORY

1948	Tokai Electronics Laboratory (original company of Hamamatsu Photonics) established.
1953	Hamamatsu TV Co., Ltd. (former name) established
1978	The 25th anniversary of foundation, the Second president Teruo Hiruma Inoguration
1983	Company name changed to Hamamatsu Photonics K.K. , Capital increased to 495 million yen.
1984	Registered on the over-the counter market of the Japan Securities Dealers Association.
1990	Central Research Laboratory opened.
1996	Registered on the second section of the Tokyo Stock Exchange(TSE)
1998	Registered on the first section of the TSE
2002	M. Koshiba, prof. emeritus of University of Tokyo awarded the Nobel Prize in physics by the establishment of the new field of "Neutrino Astronomy" where HP made photomultiplier tubes greatly contributed.
2005	"The Graduate School For The Creation Of New Photonics Industries", started.
2013	Prof. emeriti Francois Englert and Peter W. Higgs were awarded the Nobel Prize in Physics. HAMAMATSU's SSDs, APDs, and PMTs helped to detect the Higgs boson.
2015	Prof. T. Kajita ,University of Tokyo awarded the Nobel Prize in Physics, by the discovery of the Neutrino mass, where HP 's optical equipment greatly contributed .

As for the corporate mission and management policy, most of the publications are authored by Mr. T. Hiruma, the second president, [7]~[8]. The corporate mission was set down that "only breakthroughs of optical science can derive the Japanese future possibilities even without any natural resources", and it has been kept and has never wavered up to the present day.

As for industry-academia collaborations, the following consistent policy is pointed out that the predominant factor to derive the company's growth should be in as wide as possible collaborations with academic societies [9]. Actually, HP has been practicing open innovations through unaccountably large numbers of industry-academia collaborations.

As for business management, the extremely creative management systems to effectively counterbalance technological innovations and earnings by enforcing employees to keep the budget balance were pointed out. [10]~[14], namely "it doesn't matter if you do whatever you want to do, but never forget to balance your budget".

As for the local culture analysis behind the innovations, some local culture influences were pointed out, which are commonly observed in the local companies such as Yamaha Corp., Kawai Musical Instruments, Honda, and Suzuki etc. [15].

However, almost no literature referred to the innovative corporate systems in totally consistent fashion, especially from the view point of entrepreneur/engineering or the innovation analysis in a comprehensive and integrated manner based on both engineering and the theory of management [6].

IV. INNOVATIVE TARGETS ON FUTURE LIGHT ACQUISITION

The light is classified into two categories (1) visible and (2) invisible. Invisible ones are further classified into three categories as follows,

1) Classification by wavelength such as infrared, ultraviolet, radioactive ray, etc. beyond human detectability range.
2) Classification by light intensity, too weak, outside of human detectable range.
3) Classification by motion speed beyond human perceptible ability,

In any case, the definition of captured images should be as fine as possible to catch objects clearly.

The technological goals for future light acquisition are illustrated in Fig.3 [16], where the horizontal axis stands for wave length and the vertical axis for sensitivity. The reddish violet painted area shows the current state of vacuum devices and the light bluish area shows that of semiconductor devices. Vacuum devices surpass semiconductor devices in both coverage of the sensitivity and the wave length as listed below.

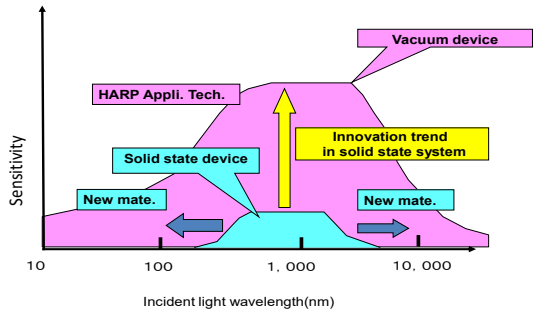

Fig.3. The goals for future light acquisition technologies, where the vacuum devices and the solid state devices are compared [16]

1) Wider wave length sensitive capability
   The semiconductor type has the demerit of unavoidable restriction on available materials, on which the detectable wave length range has to be dependent. On the other hand, vacuum devices can adopt the wider choice of photosensitive materials which enable wider wave length coverage.
2) Higher sensitivity capability
   Furthermore, vacuum devices have another merit of; negligibly small dark current (namely less noise) . On the other hand, semiconductor type is likely to generate more dark current even at ambient darkness because the electron transit space is fulfilled with photosensitive materials. Generally, the signal to noise ratio (S/N ratio) is the key factor to detect very weak optical signal and vacuum devices ultimately become advantageous over solid state types (namely semiconductor types), due to the higher S/N ratio ability.
3) Ultra-fast phenomenon acquisition capability
   The vacuum never blocks the electron path and the velocity can reach the theoretical limit, or the velocity of light. On the other hand, solid state devices apply photosensitive solid state materials through which the photo-excited electrons have to transit across and the velocity is far short of the velocity of light. The electron transit time becomes the predominant factor to capture ultra-fast phenomenon and so vacuum devices become advantageous.

However, semiconductor devices inherit the advantageous merit of compactness to broaden the application areas and can be replaced gradually by the improvement of the demerits mentioned above.

Fig.4 illustrates the photonics functional innovation goals to reach for [16]. They are summarized into four primary characteristics or (1) super sensitivity, (2) super definition (3) ultra-high speed, (4) wider wavelength detection. The details are omitted and appear in specialized books.

HP has been challenging and has cleared those key innovation goals one by one. Fig.5 shows the sensitivity innovations achieved by them where horizontal axis represents the object luminance or the number of incident

photons. HP has been challenging the ultimate goals to detect even the photon counting areas under the object illuminance of less than 10^{-5} lux (the dotted illuminance area in fig.5), except for the super HARP [16] (High-gain Avalanche Rushing amorphous Photoconductor) technology. The yellowed area indicates the illuminance area required for standard widely used cameras including TV cameras, digital cameras and so on.

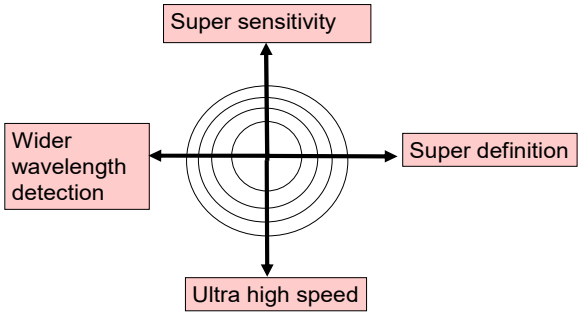

Fig.4 Photonics innovation goals

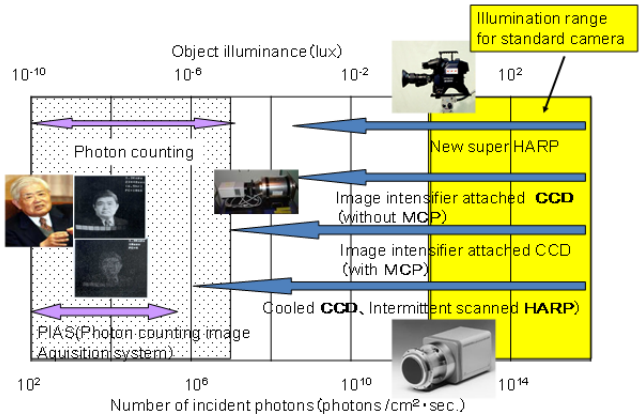

Fig.5 illustration of sensitivity innovation [16]

Fig.6 shows one of the typical innovations by HP, or world largest 20 inch diameter PMT (Photomultiplier tube) arrays installed into the Super-Kamiokannde, top world neutrino observation site constructed in an abandoned mine located in Gifu prefecture, Japan in 1996.

The larger the diameter of PMT, the more sensitive the elemental particle detection system becomes, however, the more difficult the manufacturing becomes because of the never experienced huge size. They overcome the difficulties and tackled the production of several hundred tubes with uniform quality and contributed to three Nobel Prize wins.

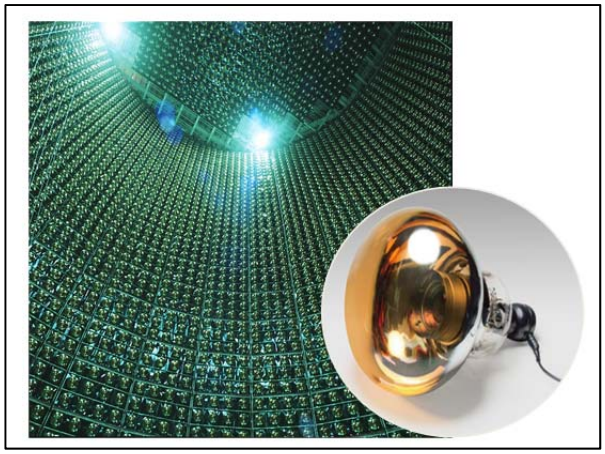

Fig.6 world largest PMT installed in the super-Kamiokande, world's top neutrino observation site [17]

V. BY NEVER WAVERING IN THEIR BUSINESS MANAGEMENT PHILOSOPHY BEHIND THE INNOVATIONS

HP has inherited the following company management philosophy shown below.

1) Pursuit of the unknown and the yet-undiscovered. Every start point should be from "the unknown"
2) The mission of HP is to search for truth, by the spirit of " Yaramaika" (dialectal expression of "in any case follow through with try and challenge")
3) "Only breakthroughs in photonics open a new possibility for Japan with fewer natural resources"
4) "Photon is our business"
5) No need of" any manuals (standardized work sheet)". It doesn't matter if you do whatever you want to do, however always keep the budget balance between earning and expense"
6) "Theory is unnecessary, however implicit knowledge is the very nature of a crown-jewel"

Under this unwavering management philosophy, engineers can try anything challengeable and are never reprimanded even if a failure as long as the budget balance is kept. Their businesses run successfully under such a very Japanese style, while letting individuals do whatever they want to do.

VI. UNIQUE SECI MODEL LIKE IN-COMPANY KNOWLEDGE CIRCULATION SYSTEM,

Photomultiplier tubes require the very delicate fabrication skills full of implicit knowledge such as the very minute sequential control of temperature, and residual gas pressure etc. which affect fundamental performances. Fig.7 shows the SECI model like knowledge circulation system practiced by HP. The on-jobsite established knowledges ① is shared in a cross-sectional manner over the entire company.

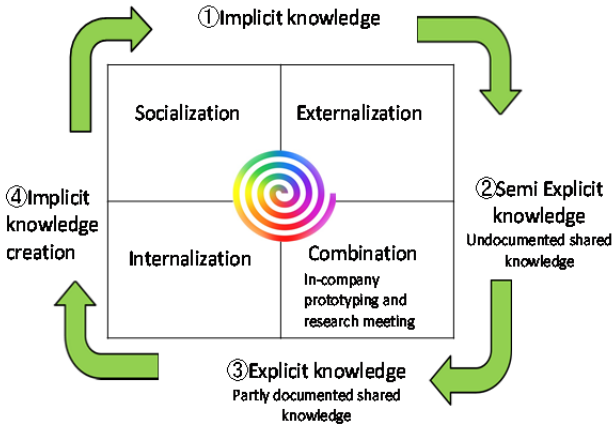

Fig.7 SECI model like knowledge circulation system in HP

The technical know-how accumulated at job sites are reported mutually at periodically held in-company workshops and shared as semi-explicit like knowledge even though still in undocumented fashion ②. It is fed back to job sites again and internalized while a part of it is documented ③. It is utilized again to create further knowledge including know-how ④. The job sites create further new knowledge based on the previous knowledge, as a form of intangible implicit knowledge. The job sites recreate further new knowledge to utilize it. Those knowledge circulation mechanisms are spirally sublimated as the "SECI" model like innovation creation system [18].

VII. OPEN INNOVATION PRACTICE SYSTEM COVERING VERY WIDE INDUSTRIAL AREAS AROUND THEIR CORE TECHNOLOGIES

Reviewed in the technical papers authored by the company engineers, the breadth of the specialized areas stands out. Above all, co-authored ones in the photonics related areas are particularly remarkable, including astronomy, physics, medical science, agriculture, broadcasting etc. The image of their open innovative collaborations is shown in Fig.8.

Against the background of the open innovations undergone, the top managers' unwavering management philosophy mentioned in 5. was found to firmly support their innovations, as seen in the wording "catch the information about whatever is needed, and then tackle it."

Actually, the top managers are always searching for new technological needs worldwide by themselves, under the concept that the market should be found by itself if we could develop world first products. Any employees can go on an overseas business trip if it is to search for a need for potential applications.

As for typical collaborative innovation samples on the physical areas, it is pointed out that the detection of Higgs bosons (bringing about mass in materials), and neutrino particle (electrically neutral but having infinitesimal mass) by super sensitive PMT (photomultiplier tubes) and SSD (Silicon Strip Detector) developed by themselves as shown in Fig.6. They played a decisive role and contributed to three Nobel Prize wins in total.

The representative innovation practices based on academia-industry collaborations are sampled below. As for medical science areas, the latest medical imaging inspection systems could bring about earlier cancer detection. As for astronomical science, the commercialization of the world's highest sensitive CCD (Charge Coupled Device) equipped on the Subaru telescope, for the agriculture area, optical detection equipment to catch the imperceptible light emitted during sprouting, by which various botanical properties can be clarified, as for light source areas including lasers, the application to research for nuclear fusion, as for imperceptibly weak light detection and ultra-high speed imaging areas, various image measurement systems and streak cameras (scanning follow shot camera) to catch the moment of explosion etc. are pointed out.

If they are requested to try something challengeable by other companies, they never refuse the requests unless they fall outside the area of photonics and interrupt other company projects.

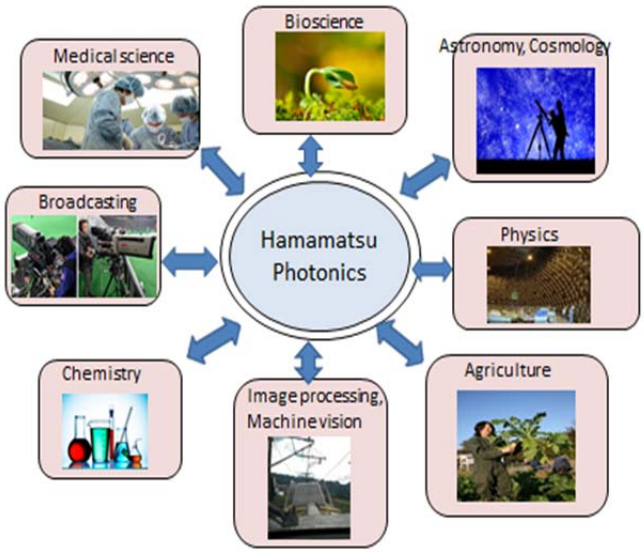

Fig.8 Collaboration Industrial areas undertaken by HP

VIII. ON-SITE COMPATIBILITY MANAGEMENT BETWEEN INNOVATIONS AND EARNINGS

They now have 46 business divisions. Among them, the money-losing ones are not more than two to three. As mentioned in the introduction, this is owing to unwavering management philosophy, "no need of manuals and employees are allowed to do whatever they want to do, however keep the balance between the earnings and the expenses".

To implement this, the company has been adopting a corporate cash-voucher system since 1975. At first, the system was only one of corporate economic activities to

reduce expenditure, but it gradually evolved to the system for the autonomous balancing of earning and expense. Thereby, the current business style which is strong enough to survive was established while doing whatever they want to do. It needed more than 10 years to be entrenched across the company as deeply as to not need to demand any reduction in expenditures.

The actual operating images are shown below. All of the individuals and business divisions can get cash-vouchers according to shipment of products (including shipment to corporate stock for sales), and pay expenditure purchased from outside or other business divisions, and the department cost (including employment cost, administration cost and R & D cost, etc.) by using the vouchers. The budget allotment and control are in principle, autonomously managed by the department or division itself. A sample of in-company cash-vouchers are shown in Fig.9.

Fig.9 Sample of in-company cash-voucher (Courtesy by HP)
Courtesy provided by HP

The SGA (Selling and General Administration) expenses are allocated fairly to each business division. Equipment and facility expenses are counted as a depreciation cost.

Originally, actual paper vouchers were issued and used but nowadays they are replaced by a computerized system and payment is made as a whole, every fixed period. On-site chiefs having an average of 10 subordinates actually manage the vouchers. The 46 business divisions are operated independently as if they were private shops.

The budget management is strictly and precisely controlled on divisional basis. However, even if business achievements were behind the self-set goal, the business divisions are never disorganized nor are wages reduced. No division ever has special limitations imposed on their business activities due to losing money. However, as long as earning and expense stays in balance, freedom of business is guaranteed. Top managers never impose "stage gate like method" to sort out the business areas. The autonomous balance mechanism such that the more the profit the broader the freedom of business is built.

For the divisional leaders, personnel training systems for them to master naturally cost consciousness and the mind set of cash-flow control are prepared.

IX. AUTONOMOUS-DECENTRALIZED MANAGEMENT SYSTEM TO MEET THEIR CUSTOMERS' NEEDS PROMPTLY

Optical industries are rooted in photonics, which need customized products featuring high-mix low-volume productions. Then, the pyramid style operational management, suitable to mass production adopted by big companies such as car makers or integrated consumer-electronics makers becomes unsuitable.

Fig.10 illustrates the value chain model in photonics from upstream to downstream. HP has been focusing their major businesses on the upstream components and devices and positioning the keystone of the value chain as the upstream origins. The value chain model seems as a reverse pyramid to become optimal to answer the customers' requests agilely and flexibly, where rather than "How to make "required for more lean and economical mass production, " What to make" should be weighed heavily.

Thus, autonomous-decentralized or reverse pyramid shaped business management system is considered optimal.

Such a value chain model leads the fabrication philosophy that things can be made even without theories and challenges should be predominant rather than theorizing. The theorizing might be entrusted to scientists. We should place much value on manual- less implicit knowledges.

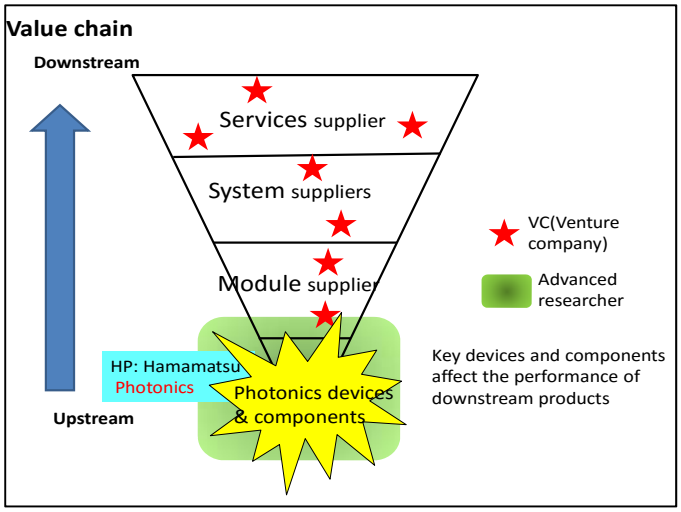

Fig.10 Value chain model in photonics

X. CULTIVATION OF HUMAN RESOURCES BY NON-ACHIEVEMENT-BASED SYSTEM

The most persons employed at the business start were mainly junior high school or high school graduates and

university graduates were few. The HP corporate culture is enrooted in the human resource discipline that the members are never reprimanded even if they failed and can make freely challenge any challengeable attempts without any manuals as long as the balance between income and expenditure is maintained.

The company set the so called “Greek day” twice a month when corporate members can spend their working times freely under the environment removing sectional boundaries and it was continued until the introduction of the two days off a week system. After the Greek day was shortened to a half day, it was succeeded as the system where members can do whatever they want to do, for example various experiments, gymnastic exercises etc.. It is contributing to foster individual entrepreneurship mind and enhance individual health as well.

Furthermore, Japanese–style bar shops located in the central areas of the city called as “Chitose sub office” where they can eat and drink with in-company vouchers, by which close communication environment is encouraged as well.

The in-company circle” Koyukai” (related voluntary clubs are 37) is organized to enhance mutual friend ship as well. Thereby, they can enjoy circle activities and receive welfare benefits as well. Thereby, a kind of familyism is fostered in the environment.

The employee’s performance is evaluated by mid managers through the individual total ability centering on developmental power. But the salary is based on seniority system. Any performance-based incentives are not introduced; however the individual performance is reflected on career advancement only.

According to the popularization of higher education, the company has been concerned about the decrease in personnel with stray Samurai spirit. The topical human resources cultivation system is the foundation of the Graduate School for the Creation of New Photonics Industries in 2005. The number of students is around 20, for doctoral course only, aiming at the cultivation of unique human resources with the startup abilities for new optical industries. The unique features are company’s support both for funding and human networks to make students inherit the company’s DNA.

HP aims to enhance the localized culture by positioning Hamamatsu as the preeminent city of photonics, so that unless working at Hamamatsu, latest optical challenges will never be developed.

XI. CONCLUSION

Hamamatsu Photonics has been unwaveringly inheriting the following spirits since the start of business, or “always challenge the unknown and yet-undeveloped photonics”. It is a typical unique enterprise undertaking purely Japanese style management making the best use of lifetime employment which nurtures employee’s fidelity to company, very unique autonomous decentralized business operation, the management structure optimized for high-mix low-volume customized production and unique seniority-based human resources management system different from the performance-based evaluation system seen mainly in advanced countries etc.. In addition to those management systems, the compatibility management between innovation and earning is well functioning across the company and contributes to keeping higher profit rate of nearly 20 % while pursuing dreams.

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