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Kaufman et al.

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[54] **LASER LINE PRINTER**

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[73] Assignee: **Craig R. Kaufman, Lois J. Kaufman, Irving R. Kaufman, Benjamin M. Wedner, Daniel R. Strick,** all of Pittsburgh, Pa., part interest to each

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[51] **Int. Cl.** **G05k 15/02**

[58] **Field of Search** .....346/1, 76 L, 108, 139 A; 178/7.6; 95/4.5 R

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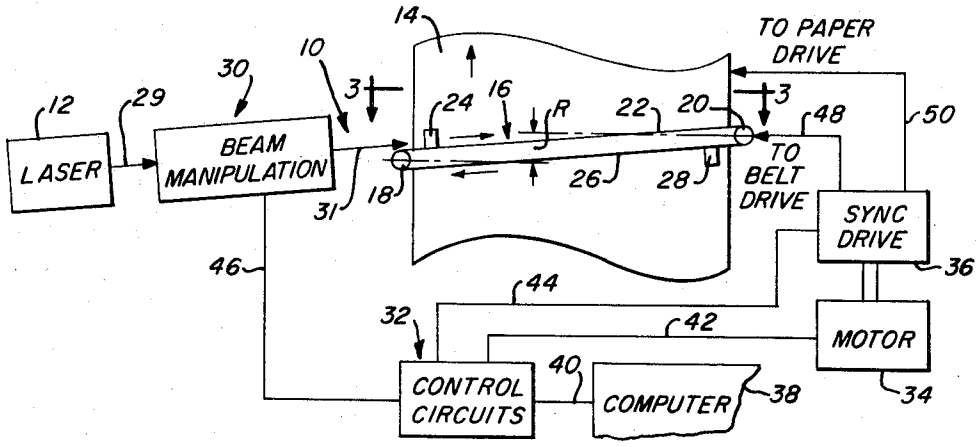
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Primary Examiner—Joseph W. Hartary
Attorney—William Kovensky

[57] **ABSTRACT**

A general purpose printer, particularly suitable for use as an output device for a computer, wherein the paper moves continuously, is disclosed. A belt having an inclined top run carries a mirror in front of the paper. The data to be printed is carried on and is made to operate an array of small laser beams directed at the mirror. By synchronization of paper motion, belt motion, and laser beam operation, straight lines of the data are generated on the moving paper by the continuously moving mirror carrying belt.

5 Claims, 6 Drawing Figures



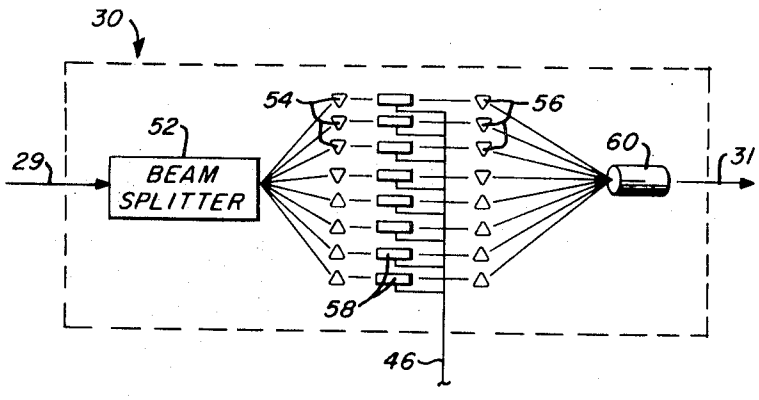


FIG. 1

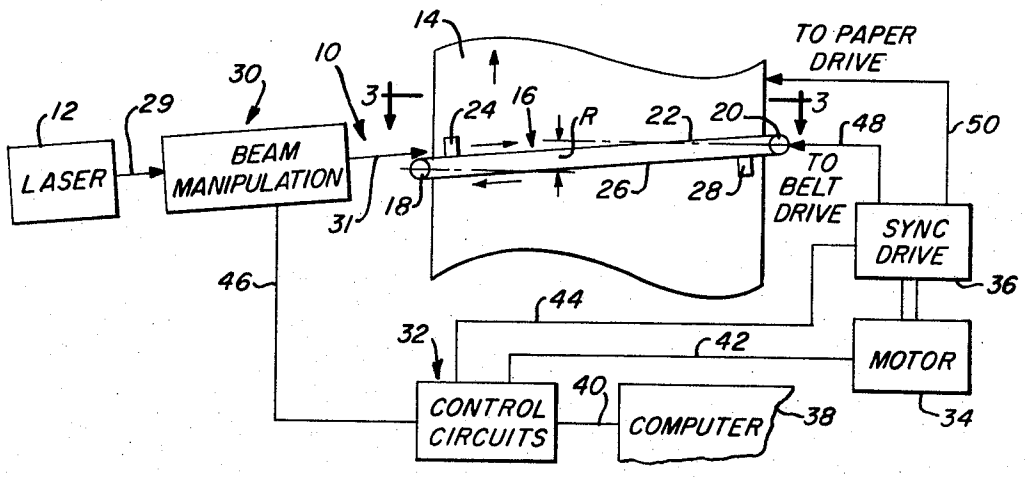


FIG. 2

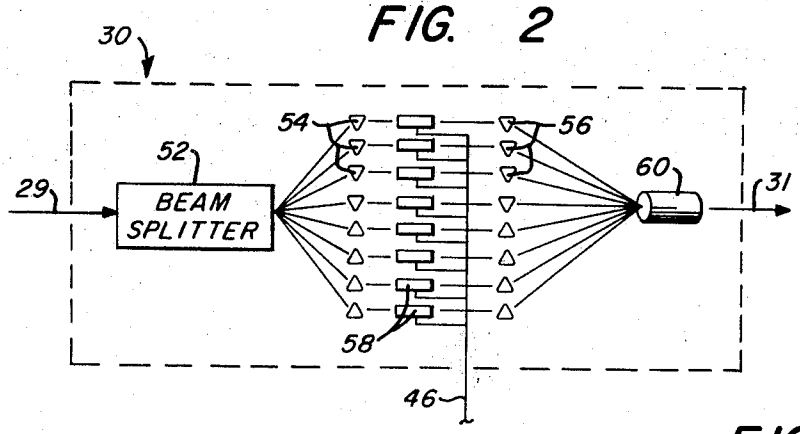


FIG. 3

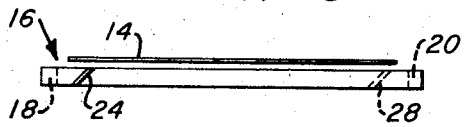


FIG. 4

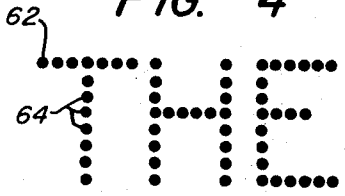


FIG. 5

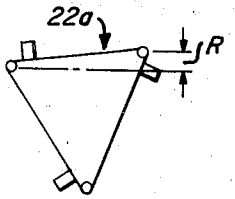
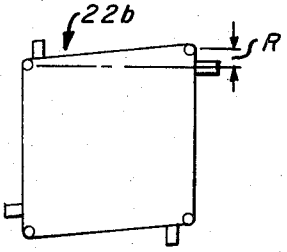


FIG. 6



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LASER LINE PRINTER

This invention pertains to a printer, and particularly such a device suitable for use as high speed output means for modern high speed general purpose digital computers. The invention is not so limited however, and can be used in any application where high speed printing is needed to follow rapidly changing data, such as facsimile reproduction, or in data telemetry in general.

The state of the high speed printer art at present is generally a highly improved mechanical device involving the creation of characters using inked ribbon and male dies, i.e., operation essentially that of a typewriter. The improvements involve mounting the type on chains, faster linkages, high speed motors, and the like. However, all such essentially mechanical printing devices suffer from many disadvantages. It is not possible to easily change the character set or type font in such devices. As the number of characters within a character set increases, the time needed to gain access to any given character increases. Still another disadvantage of such mechanical printers is the need to cause abrupt changes in direction of motion and rapid increases and decreases in acceleration in the various parts such as hammers, rachets, rollers, linkages, and the like. Still another disadvantage is the need to impart a line-by-line essentially "jerky" motion to the paper. Of course, the paper must come to a complete stop before printing a character, otherwise the imprint will be blurred, and/or the line will not be straight. This particular kind of deterioration of product quality in high speed computer driven printers is quite common. Still another disadvantage of essentially mechanical printers is the deterioration of the ribbon with use, and/or the time, expense and annoyance to replace disposable ribbons.

The newest printers use other means such as electrostatic printing, or spraying ink through dies, but such devices still have many parts which move intermittently, and they also move the paper line-by-line.

The present invention provides a printer which overcomes all of the above disadvantages, and which in addition operates at even greater speeds than the fastest printers presently available. Further, it is thought that printers embodying the invention will be very much quieter in operation than such conventional printers. The printer embodying the invention achieves these improvements, most basically, by providing continuous motion of all of its moving operative parts, thereby eliminating all the inherent disadvantages of mechanical direction changing types of mechanisms. Combined with the continuously moving parts, the invention comprises a light or light-like energy source, preferably a laser, cooperable with light energy responsive paper. This portion of the invention, data input, has no moving parts and operates at electronic speeds. Thus, all of the inherent problems in all die or ink based systems are overcome.

The combination of the invention also includes means to utilize the versatility of modern mini-computers, or the versatility of the computer driving the invention printer, to operate the laser light source in such a way as to achieve a virtually infinitely variable character set or type font. The provision of computer or computer-like control of the laser further permits

the printing of halftones so as to permit extensive creation of graphics on an otherwise ordinary output printer. Further, when coupled with the appropriate paper, multi-layered perhaps, the invention could produce full color output.

The printer embodying the invention comprises one or more belt mounted mirrors which are continuously moved in front of the light responsive paper. The active top run of the belt is inclined with respect to the direction of paper travel, in a plane parallel to the plane of the paper, and the belt and paper drives are synchronized together so that both move continuously while generating straight lines of data or "print". The mirror has a height substantially equal to the height of one character. The laser energy is directed to the mirror and then onto the paper or other laser responsive medium. The beam from the source is broken up into a plurality of separate, individually controllable smaller beams between the laser source and the mirror. By allowing certain combinations of the smaller beams from the mirror to strike the paper, with due regard to the timing of the motions of both the belt and the paper, an infinitely variable character set can be obtained. Because the laser beam does not spread or dissipate, and because the characters are built up from parts rather than imaged, no undue optical or focusing problems are encountered.

Thus, it can be seen that the printer of the invention is inherently smooth in operation because of the continuous motion of both the paper and of the belt driven mirrors. The input of data is done entirely electronically in the means which control the small laser beams.

The simplest embodiment of the invention would include two parallel runs of one endless belt, and two mirrors on the belt mounted **180°** apart, or equally spaced apart. Since a small fraction of time will exist while the first mirror is moving off of the top run of the belt as the second mirror moves onto the top run of the belt, the printer of the invention automatically creates a small vertical space between the lines of data on the continuously moving paper. The size of this space can be modified or even eliminated by making suitable changes in the synchronism between the belt and paper drives, by using additional runs of belt each with an additional mirror, and/or by reducing the size of the pulleys in the belt drive system.

The above and other advantages of the invention will be pointed out or will become evident in the following detailed description and claims, and in the accompanying drawing also forming a part of the disclosure, in which:

FIG. **1** is an overall partially schematic and partially mechanical showing of a printer embodying the invention;

FIG. **2** is a schematic expanded view of part of FIG. **1**;

FIG. **3** is a cross-sectional view taken on line **3—3** of FIG. **1**;

FIG. **4** is an exaggerated diagrammatic illustration of the word "THE" as it might be produced by a printer embodying the invention; and

FIGS. **5** and **6** are two other embodiments of the belt drive.

Referring now in detail to the drawing, reference numeral **10** generally indicates a printer embodying the

invention, with some of the parts shown schematically Printer **10** comprises a laser **12**, the energy from which is used in generating the "hard copy" of the data on paper **14**. The use of a laser as the energy source **12** is preferred because the laser beam consists of monochromatic and coherent light, thus facilitating dividing the beam and optically handling it. However, in other applications, the invention could be made to operate with ordinary light or other forms of energy. Whatever energy source is used at **12**, it is necessary that the paper **14** be responsive thereto to produce a hard copy. For example, various kinds of photographic or photographic-like papers could be used with laser or ordinary light.

Therefore, the term "paper" as used in the specification and claims shall be understood to mean any true paper or any paper-like material which is compatible with whatever particular energy source is being utilized in any particular embodiment of the invention. Similarly, the term "laser" or "laser energy" or "light" or "energy" or "beam" or the like shall be understood to mean any such light or light-like energy which, with a suitable "paper", can produce hard copies of data. Therefore, the term "printing" and its derivatives as used herein shall be understood to mean any set of a compatible "paper" and "energy beam".

Mounted front of or in otherwise operatively cooperable relation to the front or sensitive face of paper **14**, is a belt assembly **16**. In the form shown in FIG. **1**, belt assembly **16** comprises a low end pulley **18**, a high end pulley **20**, a top belt run **22** carrying a mirror **24**, and a bottom belt run **26** carrying a mirror **28**. The endless belt assembly **22, 26** is preferably made of a material which will permit the mounting of mirrors **24** and **28** thereon, which will allow a positive drive, and which will be resistive to changes in length caused by temperature or other atmospheric changes, while at the same time being highly efficient and durable in use. A suitable material might be rubber impregnated cotton or high strength metal chain. Such belts are known in the art to be capable of speeds of several thousands of feet per minute. The means to drive the belt, not shown, may be connected to either pulley **18** or **20**, and will be some appropriate conventional belt driving means. is the belt will run continuously in operation, and must merely be stable and reliable and synchronized with the paper drive, a great deal of existing technology is applicable to making this part of the apparatus of the invention, and thus it need not be explained further here, Similarly, the mirrors **24** and **28**, see FIGS. **1** and **3**, will be mounted at 45° off perpendicular to the paper **14**, so as to direct the laser energy onto the paper while, at the same time able to make the turns around the pulleys **18** and **20**. Again, such structure iw well within existing technology, and, for example, could be achieved by a rivet or other point-type mounting between mirror and belt.

Interposed between laser **12** and belt assembly **16** are means **30** for controlling the energy from energy source **12** in its travel to the mirrors on the belt assembly. Various kinds of structure to manipulate the beam and to effectually code or input the data onto the beam to transmit the data to the paper **14** are possible, and the preferred embodiment will be described below with regard to FIG. **2**. As an example of other types of structure in block **30**, a fiber optics system including some sort of blocking or switching means could be used to code data onto the beam. The arrow **29** indicates the energy passing from laser **12** to the beam manipulator **30**, and arrow **31** indicates that energy modified by having the data to be printed impressed or coded thereon in accordance with the invention. Thus, the beam **29** from whatever source may be thought of as an energy beam data carrier, with the data ladened or coded thereon in block **30**, and the resultant data carrying energy beam emerging as at **31** parallel to the direction of mirror travel.

A block **32** indicates the overall control for the entire system, which also includes a motor **34** and the synchronous drive means **36** for both the belt and the paper. A computer **38** is shown partially because it does not per se form a part of the invention, since the computer merely drives the invention printer. A line **40** interconnects the control circuitry **32** with computer **38**. A line **42** connects the circuitry **32** to motor **34** and another line **44** interconnects said control circuitry with the synchronous drive means **36**. A line **46** interconnects the control circuitry with the beam manipulating means **30**. The interconnections between the synchronous drive **36** and the belt drive means and the paper drive means, both not shown, are indicated by the lines **48** and **50**, respectively. The two drives, for belt and for paper, may be readily fabricated using present conventional technology in that both the paper and the belt move continuously. Thus, the lines **48** and **50** may represent electrical power delivered to synchronous or the like motors, or may represent some sort or physical interconnection, such as positive drives, chains, or the like. The lines **40, 42, 44** and **46**, as is well known to those skilled in the electronics and electrical arts, may represent an actual wire, a printed circuit board interconnection, or the like conductor, and may also represent a single or a plurality of electrical conductors.

The control circuitry **32** could interact with the computer **38** driving the invention in various different manners. Where the output to be printed or displayed on paper **14** consists solely of standard alphanumeric data, then it would probably be most efficient to provide the required relatively simple logic or coding needed to transform letters into beam combinations within the control circuits **32** themselves. It is contemplated that using modern solid state electronics, the necessary logic would require no more than one or two printed circuit boards or perhaps a small number of integrated circuits. This first mode or embodiment of circuitry **32** has the advantage of being very easily compatible with many different kinds of computers or other input devices because the input data on the line **40** is simply a signal representative of the actual letter or number to be displayed in some conventional code. The corresponding disadvantage of this first form of circuitry **32** is that it is fairly limited in scope. A second form which circuitry **32** might take would be simply switching circuits for the computer **38**. In this case all of the coding, timing information, and the like, would have to be programmed into the computer represented at **38**. This form has the advantage that a virtually infinite variety of final output is possible, including virtually any kind of graphical display, but has the disad-

vantage that having only switching circuits in block 32 makes the printer less universally compatible. Still a third form which the circuitry 32 might take, and perhaps the most desirable, would be some combination of the first two forms. For example, block 32 could include the logic for several fonts of characters, and some limited graphics, but also means to convert to purely a switching function if more sophisticated displays under the direct control of the driving computer are desired.

If desired, a tape buffer could be provided between computer 38 and block 30. The read head would be synchronized with the printer and the write head with the computer, whereby the speeds of computer and printer would be substantially independent of each other.

Referring now to FIG. 2, there is shown the preferred form of the beam manipulation means or data coding means 30. The raw laser energy 29 first encounters a beam splitter 52 which divides the single beam from laser 12 into a plurality of smaller beams, as indicated on the drawing. Beam splitter 52 may take the form of a fiber optical device, an array of optical wedges, an array of mirrors, or the like, as is well known to those skilled in the art.

Means are provided to individually control the separate small beams produced after the beam splitter and to impress the input data on said separate beams. To this end, there is provided a first array of prisms 54 and a second array of prisms 56. The prisms serve to align the small beams so they may be more readily handled by the electronic light modulators 58. The line 46 from the control circuitry 32 operates the modulators 58. The modulators may be thought of as high speed electronic light shutters which individually control the small beams after the beam splitter. One device which is thought to be usable as the modulators 58 is produced by Isomet Corporation of Palisades Park, N.J., their MOdel No. EOLM–400. This device has a rise time of 1 nanosecond. The small beams, with the input data impressed thereon by selective operation of various combinations of the modulators 58, are brought together again, after the second prisms 56, by a collimator 60, the output of which is the data carrying beam 31. Thus, it can be seen that the function of the beam splitter 52 and the two sets of prisms 54 and 56 is to generate sufficient physical separation between the small beams so that they may be individually handled by the modulators 58. If other technology were available, the beam splitter, the various prisms, and perhaps even the collimator, could be combined, as is obvious.

An important feature of the invention is achieving continuous operation of both the belt 22 and the paper 14 is the difference in height indicated by dimension R on FIG. 1 between the centerlines of the pulleys 18 and 20. The same dimension R appears in FIGS. 5 and 6 described below. The drawing is not to scale, but dimension R would be substantially equal to: (1) the height of a single mirror 24 or 28, (2) the maximum height of a single character, and (3) the height of the array of small beams 31 as generated by the beam manipulation means 30. The drawing was intentionally made so as to more clearly show how the beams 29 and 31 from the laser are parallel to the top run of the belt 22 without regard to scale.

Referring to FIG. 4, there is shown, somewhat schematically, the word "THE" as it might be produced by aprinter embodying the invention. The control circuitry continuously senses the position of the continuously moving mirror 24 by means of the positive belt drive. When the mirror is in the position wherein the beams 31 reflected therefrom onto the paper would produce dots at the vertical location corresponding to mark 62 in FIG. 4, then at precisely that time the control circuitry will close off all but the uppermost modulator 58 and its small beam. Operation continues in this manner until the mirror arrives at the position corresponding to the marks 64, at which time all the modulators open to pass their respective small beams to thereby produce the vertical leg of the letter T. As can now be appreciated, the rise in the belt R allows the data ladened beam 31 to effectually follow the motion of paper 14 to produce a straight line of data, the necessary timing being produced by the synchronous drive 36 under the guidance of the control circuitry 32. While this timing is highly critical, it is relatively easily obtained because belt and paper are driven both continuously and positively. Along this same line of thought, speed control would be readily achieved. A "warm-up" period will probably be needed to allow belt and paper to arrive at an operating speed at start-up.

If the modulators 58 are driven so as to be operated in a proportional rather than an on/off mode, then it can be readily appreciated how the printer of the invention can produce halftone graphics, and other sophisticated displays. Further, examining FIG. 4 again, since the dots are quite small, and a large number of them are needed to make up any letter, it is readily appreciated that these relatively small building blocks can be put together to form scientific symbols, Chinese characters, or whatever else might be desired.

For purposes of example, the drawing illustrates breaking the beam 29 into eight small beams, to thus produce a vertical array 31 eight small beams high, which, it is thought, would be sufficient for most purposes. If simpler material is to be printed then perhaps an array only five small beams high would be satisfactory. Conversely, if still more sophistication is required then a number greater than eight beams could be provided, with a concomitant increase in cost and complication. In any case, the individual spots or marks such as 62 and 64 will be formed and spaced so as to produce actual or apparent solid lines on the paper 14. The small beams could have a rectilinear cross-section for this purpose. FIG. 4 shows separate discrete marks for purposes of illustration only.

As can be readily appreciated from the drawing and the above explanation, no printing can occur during the time a mirror goes off the top run around the pulley 20 and until the time another mirror comes into the top run around the pulley. 18.Since the paper is moving continuously, this "dead time" automatically produces a space on the paper 14 extending perpendicular to the direction of motion of the paper. IF such a space is desirable in a particular useage, then it can be enlarged by simply using a two run belt system as in FIGS. 1 and 3, and providing relatively large diameter pulleys 18 and 20. In other applications it may be desired to minimize the size of this space to thereby more efficiently pack data onto the paper 14. Referring to FIGS.

5 and 6, there is shown two alternative means to accomplish the latter desideratum.

The belt 22a of FIG. 5 is of triangular configuration and has the same rise R in its top run. By providing a belt with additional runs each carrying an additional mirror, the "dead time" when a mirror is not on the top run is made smaller. In FIG. 6, there is shown a belt 22b having 4 runs, 4 mirrors, and again the same rise R. Another way to minimize non-printing time, irregardless of the number of runs in the belt, is to simply decrease the diameter of the upper left pulley, i.e., the top run pulley closest to the energy source. The rise R is related to character height and not the number of belt runs.

While the invention has been described in detail above, it is to be understood that this detailed description is by way of example only, and the protection granted is to be limited only within the spirit of the invention and the scope of the following claims.

We claim:

1. Apparatus for printing data on paper comprising means for continuously moving the paper in a first direction and in a first plane, means for continuously moving mirror means in a second plane parallel to and displaced from said first plane and in a second direction, said second direction being substantially perpendicular to said first direction and having a relatively small component parallel to said first direction, means for coding the data to be printed into an energy beam carrier, means for directing said data ladened energy of said energy beam carrier in said second direction to said mirror means and thence onto said continuously moving paper, said data coding means comprising means for dividing said energy carrier into a plurality of smaller energy beams, means for individually controlling the state of each of said smaller energy beams in accordance with said data and a code, and means for arranging said controlled smaller energy beams into a line extending in said first direction.

2. The combination of claim 1, said mirror means moving means comprising an endless belt having a predetermined number of runs and an equal number of mirrors equidistantly spaced on said belt, one run of said belt extending in said second direction, positive drive means for positively driving said belt, and synchronization means for synchronizing said belt drive means and said paper moving means.

3. The combination of claim 1, said component of said second direction parallel to said first direction being of such a size with respect to the paper dimension perpendicular to said first direction that the rise of said mirror means in its motion across said paper is substantially equal to the dimension of said mirror means in said first direction and substantially equal to the maximum height of a single data character as printed.

4. The combination of claim 1, wherein said energy beam carrier comprises eight of said smaller energy beams.

5. The combination of claim 1, wherein said energy beam carrier comprises a laser, and an electronic light modulator for controlling each of said smaller laser beams.

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